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REPORT OF THE
INTERNATIONAL SYMPOSIUM ON THE EARLY LIFE HISTORY OF FISH
Oban, Scotland, 17 - 23 May 1973

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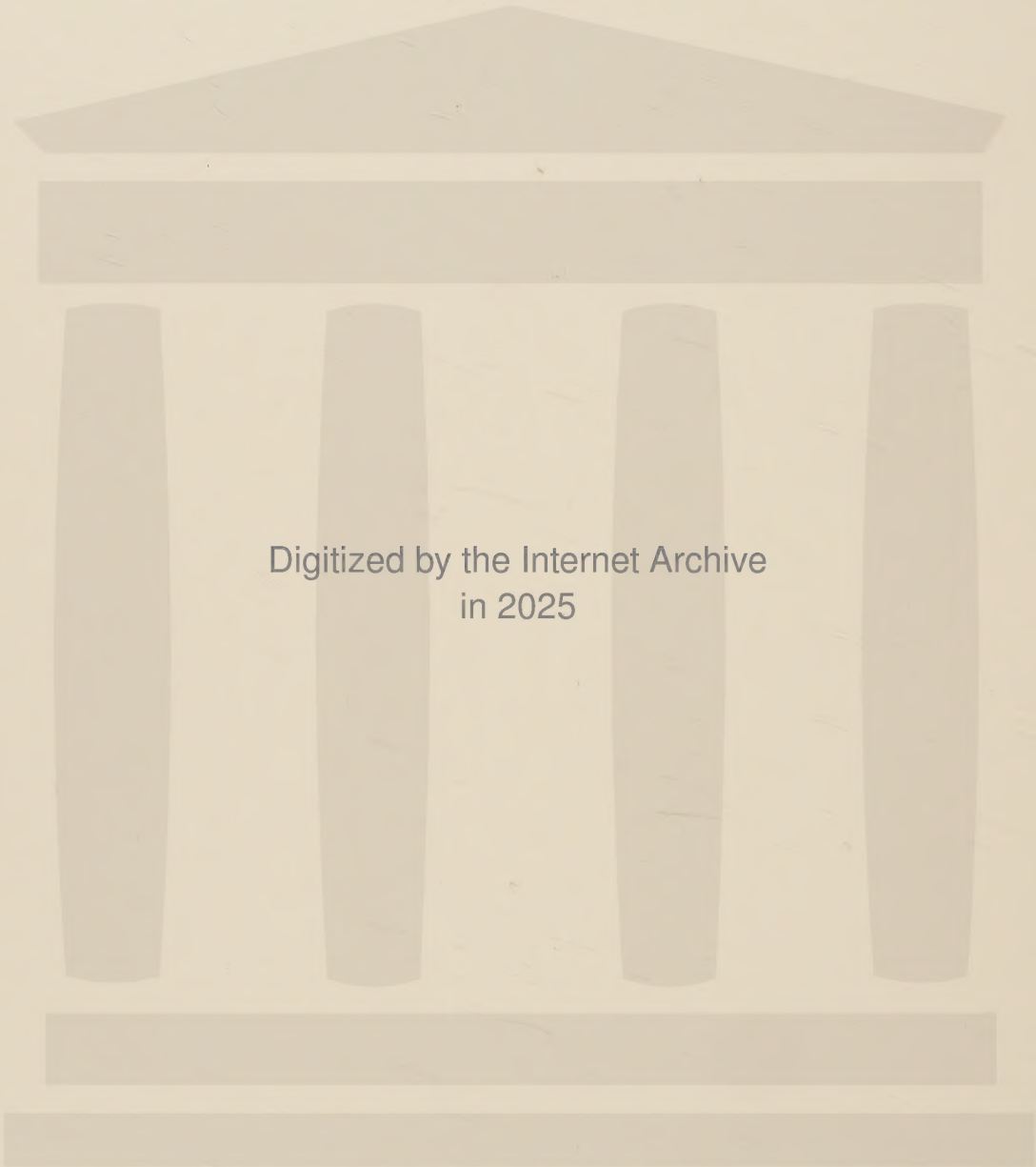
ROME, 1973



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REPORT OF THE

INTERNATIONAL SYMPOSIUM ON THE EARLY LIFE HISTORY OF FISH

Organized by

IABO in collaboration with FAO, ICES, ICNAF and SCOR (*)

Oban, Scotland, 17 - 23 May 1973

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, October 1973

PREPARATION OF THIS REPORT

This document is the report of the International Symposium on the Early Life History of Fish (Oban, U.K., 17-23 May 1973), organized by IABO in collaboration with FAO, ICES, ICNAF and SCOR.* It includes the abstracts of papers contributed to the Symposium. The scientific papers will be edited by an Editorial Board with Dr. J.H.S. Blaxter as Chief Editor, and published in due course by the International Council for the Exploration of the Sea (ICES) in the "Rapports et Procès Verb aux des Réunions". A preliminary version of the abstracts of papers submitted to the Symposium had been prepared as a background document and distributed to participants before the meeting as FAO Fish.Circ., (317)42p.

(*) IABO - International Association of Biological Oceanography
FAO - Food and Agriculture Organization of the United Nations
ICES - International Council for the Exploration of the Sea
ICNAF - International Commission for the Northwest Atlantic Fisheries
SCOR - Scientific Committee on Oceanic Research

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1. INTRODUCTION

1.1 Brief History of the Symposium

G. Hempel (Convener)

Plans for an International Symposium on the Early Life History of Fish were conceived about four years ago. At that time work on fish eggs and larvae was attracting particular attention for several reasons:

a) The efforts of FAO and of many governments to arrive at reliable estimates of the marine fish resources. As these estimates had to be based on as many independent stock assessments and productivity estimates as possible, ichthyoplankton surveys were considered as one of the valuable tools in this respect. Results of several surveys were compiled by Gulland and others in the "Fish Resources of the Ocean". Already in 1967, the FAO Advisory Committee on Marine Resources Research (ACMRR) recommended a Working Party on fish eggs and larval surveys to review their past and future potentialities for stock assessments and fishery forecasts, and to deal with the survey methodology and standardization.

b) The stock-recruitment relationship in heavily exploited fish populations has received increasing attention. This problem is linked with the question of the functioning of biological regulatory mechanisms in recruitment and the effects of drastic changes in parental stock size and environment. This has led to additional routine survey programmes and to basic work in the early life history of fish.

c) Studies on fish larvae have shown that, at least in certain families, the larvae provide a basis for answering questions on systematics and taxonomy of adult fish. With expansion of fisheries into new areas and systematic groups, taxonomic problems increase in practical importance.

d) The growing interest in problems of pollution and aquaculture has caused a considerable increase in rearing of fish from the egg stage through metamorphosis in order to provide test organisms and recruits for culture and selection studies in ponds and cages. Various conditions of food supply, temperature and salinity have been applied in rearing experiments.

In view of the rapid development in studies of fish eggs and larvae the ACMRR Working Party, at its first meeting in late 1969, recommended a symposium with major emphasis on ecological studies of populations of fish eggs and larvae in the sea and in the laboratory. Problems of systematics and taxonomy of fish larvae should also be dealt with by experts of various taxonomic groups. ACMRR passed the suggestion on to IABO and Dr. Blaxter, Oban, agreed to convene the symposium. In its preparation he was assisted by a Steering Committee whose members were charged with the planning of the various sessions including the invitation of speakers.

Several international organizations are co-sponsoring the symposium: the FAO Fishery Resources Division has prepared and distributed the brochure of abstracts and agreed to publish their final versions together with the report of the symposium; ICES will carry the major burden of publishing the proceedings, hopefully assisted financially by other organizations; SCOR, IABO (IUBS), and FAO have provided some travel funds for participants. The major part of the local expenses are being carried by the Royal Society and the Scottish Marine Biological Association which also provided the facilities of the Dunstaffnage Laboratory.

The first announcement of the Symposium received a world-wide favourable response. The number of experts intending to come and to give a paper exceeded all expectations - again an indication of the growing interest in the various fields of ichthyoplankton studies and in the morphology, physiology and taxonomy of fish eggs and larvae. Shortage of travel

funds in some countries forced several scientists to cancel their participation, often at rather short notice. Nevertheless attendance at the Symposium and provision of papers were very good and scientifically promising.

1.2 Organization of the Symposium

J.H.S. Blaxter (Convener)

The Symposium was opened by Mr. R.I. Currie, Director of the Scottish Marine Biological Association, who welcomed the participants also on behalf of SCOR. Afterwards, Prof. G. Hempel spoke on behalf of IABO and FAO. He thanked the organizers and the Royal Society for the local arrangements. He described the historical background of the Symposium and outlined its major topics (see Introduction).

During the following week, 62 papers were given by their authors, mainly in plenary sessions. On only one day was it necessary to run parallel sessions. The scientific sessions (see later) were held at the Phoenix Cinema, Oban, and at Dunstaffnage Marine Laboratory; 238 scientists from 25 countries attended the meeting, in spite of the great difficulties experienced by many participants in raising travel funds from national or international sources. The efforts of FAO, IABO and SCOR in providing travelling expenses were highly appreciated. Participation of some scientists was also facilitated through FAO/UNDP Fishery Projects.

The Steering Committee (Annex 5.2) held three meetings during the Symposium to make last-minute adjustments to the programme and to discuss the future publication of Report and Proceedings. The final publication may cause considerable problems in view of the great number of excellent contributions, the need for rapid publication and the shortage of publication funds in ICES. It is hoped that a substantial contribution by ICNAF will help in this respect. Strict deadlines for final submittance of manuscripts were fixed and firm rules for scientific editing were established. Dr. J.H.S. Blaxter agreed to be Chief Editor of the Proceedings, with the Steering Committee acting in a general editorial capacity.

The participants of the Symposium attended a reception by the Provost of the Town of Oban on 17 May and a Symposium Dinner on 19 May. On 21 May they were invited to visit the Dunstaffnage Marine Laboratory, where they met the scientific staff of the Laboratory. An excursion was also arranged to visit coastal and freshwater sites and a trout farm in the western part of Scotland.

2. PROGRAMME

May 1973	Morning	Afternoon
Thursday 17	Population Studies Chairman: Dr. D.H. Cushing Rapporteur: Mr. R. Jones	Population Studies (continued) Mr. A. Saville Mr. R. Jones
Friday 18	Population Studies (continued) Chairman: Prof. G. Hempel Rapporteur: Mr. J. Jones Behaviour Chairman: Prof. G. Hempel Rapporteur: Dr. R.N. Gibson	Feeding and Metabolism Prof. K. Lillelund Dr. K.F. Ehrlich
Saturday 19	Physiological Ecology: Response to the abiotic environment Chairman: Dr. R. Lasker Rapporteur: Dr. D.N. Outram	Physiological Ecology (continued) Dr. D.F. Alderdice Dr. D.N. Outram Population Studies (continued) Chairman: Mr. J.J. Zijlstra Rapporteur: Mr. J. Jones

Monday 21	Taxonomy Chairman: Dr. E.H. Ahlstrom Rapporteur: Dr. W.J. Richards	Taxonomy (continued) Dr. W.J. Richards Dr. E.H. Ahlstrom
Tuesday 22	Distribution Chairman: Prof. O. Dragesund Rapporteur: Dr. J.D.M. Gordon	Rearing Mr. O. Ledoux Mr. A.B. Bowers
Wednesday 23	Developmental Events and Manipulation Chairman: Prof. C. Hubbs Rapporteur: Dr. C.C. Lindsey	

3. SESSION REPORTS

3.1 Population Studies

D.H. Cushing, G. Hempel and A. Saville (Chairmen)
R. Jones (Rapporteur)

The lack of a convincing empirical relationship between spawning stock size and subsequent recruitment is a well known phenomenon in many species; evidence confirming this view was presented during the meeting in papers by Bannister et al. for southern North Sea plaice, and by Jones for northern North Sea haddock. A number of authors examined in detail particular stages between spawning and the subsequent recruitment, dealing particularly with the egg and the larval stages. In general, the evidence suggested that the lack of correlation between the spawning stock and recruitment did not apply between all intermediate stages and that reasonably good correlations could be obtained between spawning stock and egg production on the one hand, and between late larval abundance and subsequent recruitment on the other. For example, Saville et al. investigating the relationship between spawning stock and egg production for the spring-spawning Clyde herring, showed that there was a significant positive correlation between estimates of spawning stock and subsequent egg production in the same years. Cushing examined the relationship between numbers of larvae and subsequent year-class strength in southern North Sea plaice and showed that larval abundance and subsequent recruitment were positively correlated. Evidence suggesting that the lack of correlation in the stock-recruitment relationship often occurred between the spawning stock and some point in the larval stage was provided by several authors. Cushing, for example, showed a lack of correlation between spawning stock and subsequent larval abundance for southern North Sea plaice. Saville et al. showed the same for Clyde herring. The conclusion appeared to be that the lack of correlation between stock and recruitment is usually due to processes that operate at some time during the larval stage.

Factors causing a breakdown in the empirical stock-recruitment relationship, such as changes in the abundance of eggs and larvae due to mortality and environmental effects, were considered by a number of authors. Bannister et al. calculated the mortality rates of the eggs and larvae of the southern North Sea plaice. They showed that the very good year class of 1963 started out with about an average number of eggs and was good because of a lower than average mortality rate, especially in the larval stage. A similar situation was described by Riley for sole in the Blackwater estuary. He showed that the very low presence of sole larvae in the plankton in 1970, as compared with 1969, was due to a lower survival rate in 1970. Factors that might influence egg and larval survival were discussed and these included larval drift, salinity, pollution, the quality of the spawning products and temperature. Temperature, in particular, was a factor that attracted a good deal of discussion. Dickson et al. made the suggestion that the timing of larval production might be influenced by sea temperature and presented a negative correlation between spring sea surface temperatures and subsequent year-class strengths in southern North Sea cod.

It seemed to be generally accepted that egg development is optional within a certain temperature range for each species, and Postuma and Zijlstra took account of this in their investigation of North Sea herring. They showed how the correlation between spawning stock and the abundance of larvae up to three weeks old could be improved when the effect of temperature on hatching time was taken into account. Pinus investigated year-class strength in Clupeonella delicatula and showed that better year classes resulted in years when eggs experienced 20 days as compared with only 10 days of optimal temperature conditions (15-18°C).

The whole critical period concept was well reviewed by May, who reminded the meeting that it was Hjort who had first suggested that year-class strength might be determined due to food limitation during the early larval stages. May concluded that there was circumstantial evidence in favour of this view for some, but not necessarily for all species.

The existence of a stock-recruitment relationship presupposes some density-dependent mortality process during the early stages and although no one was able to demonstrate this directly, there was discussion of how such a process might operate if it did indeed exist. Both predation and shortage of food were considered in this respect and it seems likely that no single density-dependent process could be equally applied to all species. For haddock, Jones pointed out that the larvae grow up with their prey in such a way that for a limited period the larvae tend to be restricted to prey organisms produced during only a limited part of the production cycle. He pointed out how, in this situation, the food supply could set an upper limit to numbers independently in species such as cod and haddock that spawn consecutively. For herring, Saville suggested that overproduction might be controlled in years of high egg production by the deposition of eggs in layers. He cited one instance in the Clyde herring when eggs were deposited 10 layers deep and where the bottom layers consisted of dead and decomposing eggs.

A number of papers, and considerable discussion, centred around the collection, use and interpretation of egg and larval survey data. Two papers, those by Gjøsaeter and Saetre and by Tanaka, dealt with the estimation of spawning stock size from egg surveys. The authors of both papers considered the method to be a useful one and Gjøsaeter and Saetre were able to obtain an estimate of stock size from egg surveys that agreed quite well with an independent estimate based on acoustic surveys. Southward and Demir looked at the results from egg surveys of the Cornish pilchard and showed how egg diameter fluctuated cyclically and seasonally.

A number of papers dealt with the distribution and seasonal and annual variations in larval abundance. Hart considered the distribution of larval Ammodytes marinus in the North Sea and examined annual fluctuations in abundance in seven sub-areas for the period 1948-68. Nellen examined the distribution of fish larvae and plankton at a submerged bank off West Africa and showed that there were fewer plankton organisms and fish larvae over the bank than close beside it. Bainbridge et al. investigated the distribution of fish larvae over a part of the Northeast Atlantic and also showed how different species produced their larvae at different times in relation to the production cycle.

Two important papers by Dragesund and Bjørke and by Schnack and also a film presented by Marak dealt with a comparison of the relative efficiencies of different sampling gears. No recommendations were made in favour of any particular gear, but it was emphasized that when standard sampling was done for a long period using the same gear calibrations should be repeatedly carried out by comparing it with other and newer gears. It was also emphasized that nets should always be examined for evidence of extrusion of larvae through the meshes and clogging in general, since this might seriously reduce net efficiency. The possibilities of net avoidance, especially by day, had always to be kept in mind.

3.2 Feeding and Metabolism

K. Lillelund (Chairman)
K.F. Ehrlich (Rapporteur)

The survival of young fishes is affected by many factors; among these are rate and manner of yolk utilization, food abundance, food composition and predation. The mechanism of yolk utilization was discussed by Bachop in relation to the giant nuclei of the syncytium enclosing the yolk. The presence of these giant nuclei was peculiar to teleosts and it was suggested that significance of polyploidy in relation to metabolism of yolk should be considered. Ishibashi, working on Tilapia sparmanii, found at hatching a water content of only about 45%, but this increased during resorption of yolk. This appeared to be quite low as compared to other species, but it was suggested that this was due to inclusion of the yolk in the water content analyses. It was also shown that the rate of jaw growth was highest during the 72 h following hatching, an important factor at the commencement of feeding.

The availability and preferences of food by larval fishes was discussed by Marak and by Mendiola. Marak showed that redfish were "opportunistic" feeders with the exception of crab zoea, which were abundant in the water but not in their guts. Both redfish and larval anchovies (Mendiola) fed largely on small zooplankters, but anchovies larger than 90 mm started to consume increasing quantities of phytoplankton. The survival of larval redfish might be affected by competition since many other species utilized the same food. In larvae such as those of redfish, with long larval stages, the succession of small plankters was important for feeding. The physical requirements for feeding appear to vary between species; redfish can feed in darkness but the anchovies cannot. The occurrence of feeding larvae was highest in winter in the Peruvian anchovy.

Ehrlich showed that if larval herring were deprived of food the body water increased in relative terms but decreased in actual amount. Triglyceride, carbohydrate and protein decreased during starvation but at different rates. The greatest source of energy was from utilization of protein. There was a break in rate of deposition of body stores around 20 mm body length. It was suggested this could reflect a critical size in relation to feeding. All work on chemical composition of larvae was length-specific.

Predation of anchovy larvae by euphausiids was discussed by Lasker. It was shown that the predation was not affected by presence of alternate prey, nor by 2-3 days of starvation of euphausiids, nor by their moulting condition. The euphausiids might capture the larvae by detection of tail beats.

This session showed some of the problems related to the study of factors influencing larval survival and growth. Feeding behaviour and the conditions necessary for it varied between species. It was suggested that the ability of larvae to capture food could vary with the condition of the food. In addition, factors such as temperature would affect the behaviour and physiology of poikilothermic animals. The role of temperature in relation to feeding, and physiology with respect to growth and survival of larvae, needed to be considered.

3.3 Behaviour

G. Hempel (Chairman)
R.N. Gibson (Rapporteur)

The basic theme of the session was the relationship between larval activity and feeding, starvation and certain environmental factors. Hoagman showed that if feeding speed, searching volume and feeding efficiency, based on experimental observations, are calculated, together with estimates of food requirements based on digestion and starvation rates, and are then compared with natural food availability, starvation in wild Coregonus clupeaformis larvae seems unlikely. In fresh water it seems likely that food particles are randomly or evenly distributed, but in the sea it is known that food is found in relatively discrete

patches. Starvation, or at least deprivation, might thus occur unless larvae can find and remain in such patches. Hunter and Thomas's paper was concerned with this problem. They demonstrated experimentally that Engraulis mordax larvae are able to regulate their swimming and feeding behaviour according to prey density, and tend to aggregate in food patches. The discussion centred on the problems arising when complicating factors intervene, such as fixation upon one prey species, thereby imposing "patchy behaviour" upon patchiness of food supply on the sensory mechanisms involved in remaining in a patch (there is a possibility that a larva could remain in a patch simply by stopping, as it does, each time it captured a prey), and on the question of how larvae initially find a food patch. It was considered unlikely that larvae actually direct their activity toward patches, but on the other hand they do not search at random either. It must be concluded that little is known of the effect of these complicating factors.

An additional complication in the behaviour of the larvae arises when effects due to oil pollution have to be considered. Although it seems unlikely that mortality due to oil dispersants is common, the effect of these dispersants is such that they may reduce feeding time by inducing narcosis. Such narcosis may also increase the risk of predation.

It is conceivable that many larvae may not encounter sufficient food and that starvation may ensue. If this is the case, then what are the chances of the larvae being able to feed again if a new food source is found? Blaxter and Ehrlich introduced the concept of the "point of no return", equivalent to Hoagman's "ecological death", after which a larva, although still alive, is too weak to feed. They considered the effects of starvation upon buoyancy and activity and the results of such changes upon differential selection of larvae by sampling devices.

One common factor of all four papers was the dependence of many behavioural and physiological functions upon larval size, and hence the varying probability of survival at different ages.

3.4 Physiological Ecology

R. Lasker and D.F. Alderdice (Chairmen)
D.N. Outram (Rapporteur)

Species tend to show considerable diversity in levels, ranges and domains of tolerance to environmental conditions, and in their ability to undergo structural or functional adaptations within the boundaries. Increased attention appears to be needed in the definition of tolerance limits and vital capacities in order to predict the effects of natural and pollutant levels of environmental alteration, and in the search for means of optimizing production of resources by aquaculture techniques.

The papers presented in this section provided a sampling of some of the areas in which problems occur and in which more detailed knowledge is required. They ranged from an identification of basic structure and function (De Silva and Tytler; Rice and Stokes), a consideration of environmental baseline requirements in relation to tolerance and functional capacity (Hokanson and Kleiner; Irvin; Siefer, Spoor and Carlson) to the alteration of natural environmental factors to abnormal and even lethal levels (Hoss, Hettler and Coston; Powles; Hubbs and Bryan; Pommeranz), and to the occurrence of pollutional levels of natural and unnatural substances in the aquatic environment (Rosenthal and Sperling; Smith).

A number of the contributions identified single factor baseline requirements of specific organisms with respect to natural environmental entities. They were indicative of the type of information needed for many other species of direct or indirect commercial importance. In the same sense, other papers demonstrated the need for further information on the limits of concentration of abnormal environmental substances associated not only with survival, but also with viability of species subjected to pollutional effects. The paper on hydrogen sulphide indicated the hitherto probably unrecognized importance of this substance at extremely low levels in the freshwater environment.

The specificity of temperature effects noted in some papers strongly indicates the need for studies of developmental bioenergetics in commercial marine species. Further considerations of the role of temperature regarding net production efficiency in aquaculture technology could be of major economic value in optimizing production.

In the broader view, much comparative physiological inquiry tends to be restrictive in potential application to ecological problems, because of the relative simplicity of the laboratory environments employed. Such investigations tend to define tolerance and capacity of organisms with some considerable precision, but cannot predict the extent to which such tolerance limits or capacities may in fact be utilized in the real environment.

Physiological ecology may be defined as the ecological interpretation of relations existing between organismic adaptive responses and environmental properties, most often as measured in the laboratory. It is suggested that more meaningful applications of physiological information to ecological problems may be obtained in several ways. Laboratory investigations of tolerance or capacity could be made over more complex environmental domains by increased attention to experimental design - as such factors cannot be expected to operate unilaterally in natural situations. Considerations of multiple physiological responses to environmental domains should provide increased insight into effects on biomass as opposed to individual organisms. Finally, it is inferred that more intimate relations need to be formed between laboratory, discipline-oriented inquiries and field, problem-oriented operations. Closer association of the two areas of inquiry should allow a greater search for correspondence between information derived in the laboratory and its testing by hypothesis in the field situation.

3.5 Taxonomy

E.H. Ahlstrom (Chairman)
W.J. Richards (Co-Chairman and Rapporteur)

Nine papers dealing with the taxonomy of larval fishes were presented at the taxonomy plenary session. These papers can be conveniently divided into three separate groups. The first group pointed to the role of larval characters in differentiating taxa and defining evolutionary lineages within a family or groups offamilies. This group consisted of three papers. The first by Moser and Ahlstrom discussed the family Myctophidae. They showed convincing evidence that larvae demonstrate generic and subfamilial relationships better than the adults. Sequential photophore development and the appearance of specialized features, body shape, eye shape and pigmentation were some of the features employed. The second paper by Okiyama dealt with relationships of families within the suborder Myctophoidei. Using larval characters, it was shown that a close relationship was evident between the families Aulopidae and Synodontidae, and that all of these families in the suborder were derived from aulopid-like stock. The third and final paper in this group by Ahlstrom demonstrated that photophore development within the families Gonostomatidae and Sternoptychidae indicated that the maurolicine type gonostomatids were more closely related to the sternoptychids than to the other gonostomatids. He concluded that one family should be recognized - the Sternoptychidae with two subfamilies, the Sternoptychinae and the Gonostomatinae.

The second group of papers dealt with critical evaluations of the state of the art of larval identifications in two groups of fishes. The first paper by Richards and Potthoff showed that the techniques which have been used to identify the closely related species of Thunnus were not entirely valid. A study of the axial skeleton yielded different identifications than those obtained by the traditional use of pigmentation characters. They had much greater confidence in the axial skeleton characters for identification and they recommended that wherever identifications of closely-related forms based on pigmentation are found, a careful re-examination was called for. The second paper by Ueyanagi described the current state of larval billfish identifications. Based on characters used to identify the several species of Tetrapturus and Makaira in the Indo-Pacific Ocean, their cognate species could be identified in the Atlantic Ocean. It was pointed out, however, that not all the larvae have been collected for all the adults which have been reported from the Atlantic. Additional evidence was presented that intraspecific variation in larvae may indicate different subpopulations.

The third group of papers was based on studies of developmental series of larvae which shed light on identification problems. Balakrishnan described several larval series of flatfishes of the genera Solea and Cynoglossus from an Indian estuary. Matsuura described the larval development of two clupeoid fishes Pellona and Chirocentrodon and commented on their relationships based on the larval features. Khan and Faber described the dissimilar larvae of Myococephalus from fresh or marine stocks of supposedly the same species. Yusa described the early development of Limanda yokohamae and showed that features of the egg and larval development of this species indicated that it was specifically distinct from the previously synonymized L. shrenki.

3.6 Distribution

O. Dragesund (Chairman)
J.D.M. Gordon (Rapporteur)

With the exception of the paper by Wyatt, the theme of this session was the vertical and horizontal distribution of fish eggs and larvae in relation to the environment. The sampling areas varied widely from the spot stations of Seliverstov to the whole of the northern part of the Indian Ocean in the paper by Peters.

Seliverstov presented data on the vertical distribution of herring larvae in relation to the time of day and the length of the larvae. The samples were collected by a vertical array of closing plankton nets at 25 metre intervals from the surface to the bottom. Much of the discussion was concerned with the techniques used and in particular the net at the surface. The importance of sampling the top few centimetres, even when they appear to be well mixed by wave action, was stressed by a number of participants.

Miller's paper considered in some detail the distribution of larvae in coastal areas and in particular he dealt with the distribution around a small island which had a strong current flowing past it. His results indicated that the highest concentrations of larvae were found in front of the island and not in the eddies to the rear as might have been supposed. Miller invoked active selection by the larvae as the most likely explanation and much of the discussion involved this aspect of the problem. An interesting point made on the paper which was not taken up in the discussion was the value of such work in determining the most suitable areas for effluent discharge in a coastal situation.

Williams and Hart considered the seasonal and vertical distribution of larvae at Station India, an area of 100 square miles of the Atlantic close to the Rockall Bank. Ninety percent of the larvae were of Maurolicus pennati and its occurrence was clearly correlated vertically with the 9°C isotherm and seasonally with the peaks of zooplankton production. This paper also provoked an interesting discussion on the role of Sagitta as a possible predator.

All three papers would have benefited from a greater understanding of the overall distribution of the species concerned and it was in this respect that the paper by Peters was of interest. His study of the distribution of eggs and larvae in the Indian Ocean during the monsoon seasons clearly demonstrated the aggregations caused by ocean currents and upwellings. Only total numbers of eggs and larvae, irrespective of species, were considered but when these collections have been identified they will provide valuable information for more detailed studies in particular areas.

The paper by Wyatt considered a specialized instance of feeding in relation to the distribution of prey, and might have been better placed in the Feeding and Metabolism section. Plaice and sandeel larvae feed almost exclusively on Oikopleura at certain times of the year and Wyatt proposed an interesting hypothesis to account for the lack of competition. This paper stimulated an interesting discussion on whether a true estimate of the number of Oikopleura eaten could be made simply by counting the number of faecal pellets. Wyatt also introduced the concept of encounter rate which was estimated as the cube root of the product of density of prey and predator. A vigorous discussion ensued as to whether simple food density measurements should have been used.

3.7 Rearing

O. Ledoux (Chairman)
A.B. Bowers (Rapporteur)

The papers presented to this session were concerned directly or indirectly with rearing techniques. They also provided basic information on development of larval fish and the effects of varying physical and nutritive conditions on their survival and growth.

Prespawning conditioning of parent fish was considered by René and by Lasker, who reported that manipulation of photoperiod and/or temperature regimes could induce maturation of gonads outside the natural period. The examples quoted were winter-spawning fish, conditioned by reduction in temperature and day length, but Lasker suggested that any fish could be brought to maturity at a required time if the appropriate day length were found.

The primary object of Billard, Petit and Jalabert's experiments on diluted milt for artificial semination of trout eggs was to extend the number of eggs that could be fertilized by one male; it was not suggested that diluted milt produced better results than the usual techniques of artificial semination. Their experiments produced new information on the viability of eggs and sperm in various media, and photomicrographs with the scanning electron microscope showed that the time limit between shedding of eggs and fertilization was set by closure of the micropyle, and the time limit for sperm by breakdown of the plasma membrane and distortion of the mitochondria.

The importance of food quantity, quality and size of food particles in larval feeding was stressed in all the papers on fish rearing experiments. Critical stages were at first feeding, at change-over to larger food as the fish larvae grew and at the time of organogenesis. The importance of the diet of food organisms where live food was offered and the value of "green water" for culturing food emerged from the papers and discussions. The ciliate Fabria salina, the rotifer Brachionus plicatilis and the branchiopod Artemia salina seem to have a very wide application in larval fish rearing. An extensive series of experiments by Flüchter to determine whether the ciliates present in sole cultures were essential to successful rearing led him to conclude that it was not ciliates but a soluble organic substance present in the water that was essential. The extensive discussion on this surprising hypothesis centred on a close examination of the experimental technique to see whether alternative explanations of experimental results could be found.

The illustrations of larval development in Sparus, Dicentrarchus and Scophthalmus provided new information on larval morphogenesis, and interesting observations on larval behaviour emerged from the film, the papers and discussion. The work of René and Barnabé indicated that commercial farming of Sparus and Dicentrarchus should soon be achieved, while the complementary papers of Girin and of Jones, Alderson and Howell marked considerable progress in rearing Scophthalmus, which promises to be a valuable cold-water marine farm fish.

The papers presented at this session and the resulting discussions, both formal and informal, suggest that sufficient knowledge has now accrued to make possible laboratory rearing of a wide range of fish species, provided that the parent fish can be obtained. Induced spawning by environmental manipulation or by hormonal treatment is an established technique. It has been shown that selection of an appropriate physical environment in terms of tank size, salinity and temperature regime can be made to suit the developing fish. Culture techniques have been developed for live foods of a size and quality suitable for many types and many stages of larvae. Micro-encapsulation offers the possibility of a synthetic food for all development stages of the fish. Critical experimental work is still required to determine optimum rearing conditions; this session has indicated that such experiments can be planned with some confidence and the results applied to commercial exploitation of desirable species.

3.8 Developmental Events and Manipulation

C. Hubbs (Chairman)
C.C. Lindsey (Rapporteur)

Papers were presented on brain dimensions in young herring and trout (Packard and Wainwright), salinity and temperature effects on development of garfish (Fonds, Rosenthal and Alderdice), and on gynogenesis in fish (Stanley and Sneed; Purdom and Lincoln). In addition to the material outlined in the Abstracts, the following points emerged during discussions: Packard and Wainwright felt that the brain is the "central animal", wherein is recorded the life and times of the individual. Whether the change of brain size with larval growth was based on increasing cell numbers was partly answered by reference to changes in DNA content, but glial and neuronic cells were not separated in the analysis. The continued post-hatching development of the brain, strikingly different from mammalian neural ontogeny, might be related to the indeterminate growth of most fishes and to the "precocious" birth of fish compared with homoiotherms. Fonds et al. showed that general developmental activities were influenced by the coordinated effects of temperature and salinity during incubation. Although the phenotype was environmentally plastic, the rate and pattern of responses, as well as the morphology, characterized the species. Each genotype had its own range of environmental responses, as it had for optimal survival. Perhaps the methodology used here might be useful in optimizing the morphology of fish harvested in aquaculture.

Stanley and Sneed proposed the use of gynogenetic (and sterile) fishes in evaluation of possible exotic fish introductions. Purdom suggested triploidy as having more promise than gynogenetic fish produced by cold shock. Gynogenetic fish produced by radiation of sperm might suffer from remnants of paternal chromatin fragmented by radiation. The possibility of behavioural differences between normal and gynogenetic fish was suggested. Growth rates of gynogenetic fish might also be slower than that of "normal" diploid fish, as triploids and tetraploids often grow very quickly.

Purdom and Lincoln suggested that plaice/halibut "hybrids" might result from gynogenesis rather than from fusion of parental gametes. Progressive accumulation of abnormalities seemed to preclude survival to the feeding stage. The lack of true plaice/halibut hybrids was apparently not due to dimensions of the sperm and micropyle, since larger sperm from other species was effective. Difference in spawning depth (pressure) was not likely to be involved, as fertilization was in a liquid medium and as Pacific halibut had been artificially fertilized at surface pressures.

At present the knowledge of fish genetics and selection was totally inadequate to meet the needs in the growing field of aquaculture. Techniques now available in scientific horticulture and livestock breeding were urgently needed for a variety of potentially rearable fish species.

4. GENERAL CONCLUSIONS

G. Hempel (Convener)

The purpose of the Symposium was to review the present state of knowledge in important fields of research in larval fish biology. This summing-up will be made to draw some conclusions for future work. Out of the 62 papers presented, only a few will be mentioned specifically.

Objectives of studies on fish eggs and larvae

Motivations for research on fish eggs and larvae seem to be rather different from author to author and, although four major targets are obvious, mixed motivations are rather common.

Objective 1: We want to know more about fish eggs and larvae per se, for example, about embryonic and larval development, about physiology and behaviour, growth rate and mortality, taxonomy, systematics and zoogeography. The scientific importance of these studies - quite apart from any application, was emphasized by Ahlstrom and Moser, who demonstrated the importance of taxonomic research in larval myctophids for clarification of systematics of this group of fish in general. Morphogenesis, and particularly the development of behavioural patterns and of physiological functions, are of general biological interest in view of the changes from a pelagic egg and almost passive yolk-sac larva to a freely moving and feeding post-larva, and later on to a shoaling or demersal juvenile fish. This is connected with drastic changes in the diet. Amongst the vertebrates, only fish and amphibians pass through several developmental stages with such great biological and ecological differences. Jones pointed to the enormous growth rate in fish larvae which is partly counterbalanced by high mortality; again a feature which is far more pronounced in fish than in higher vertebrates.

Objective 2: We want to know more about marine and freshwater ecosystems. Fish eggs and larvae are sometimes important prey organisms, predators and grazers. Furthermore, fish eggs and larvae can be used as indicators for the state of pollution and for natural and man-made changes in ecosystems. An evaluation of such a role for ichthyoplankton was not made in detail during the Symposium, but it was stressed several times that larval populations are part of the ecosystem and that they react to any change in the system and its relationship to the abiotic environment.

Objective 3: We want to be able to rear fish eggs and larvae for various purposes for aquaculture, re-seeding and introduction of fish populations in natural and artificial habitats. Furthermore, there is an increasing need for a continuous supply of fish eggs and larvae of well defined origin for toxicity tests and other physiological experiments, as well as for any selective breeding and for genetical experiments. Rearing of fish larvae is a well established method during identification of undescribed or poorly identifiable larvae. Considerable progress toward this group of objectives was reported both in papers and in verbal discussions during the Symposium.

Objective 4: We want to know more about fish populations and so we use eggs and larvae as indicators of the existence of adult stocks, as measures of parent stock size and as a means to forecast future recruitment. Furthermore, we use egg and larval studies to differentiate between man-made and natural effects on fish stocks, e.g., decreasing recruitment from constant larval production has been taken as an indicator for increasing pre-recruit mortality due to fishing for juveniles. Tanaka has shown how egg and larval surveys can compete successfully with other methods (catch statistics, acoustic and fishing surveys) at least under certain circumstances such as those in the Japanese sardine fisheries. The results of a new method developed by Gjøsaeter and Saetre for the estimate of the Norwegian capelin stock from the number of demersal eggs agreed satisfactorily with other assessments of the same stock. It seems easier and more reliable to describe long-term changes in the abundance and distribution of fish stocks by long time series of ichthyoplankton data than from fisheries which are subject to drastic changes in effort, efficiency and fishing area. Examples of long-term observations were provided for several fish populations of the northeastern Atlantic by Harding, Postuma and Zijlstra, Bainbridge and Hart and by Saville.

It was generally recognized that application of studies of fish eggs and larvae on assessment of fish populations and ecosystems, and on aquaculture and pollution assessments, has to be based on the knowledge of taxonomy, biology and ecology. On the other hand, it was considered unrealistic to let those applications wait until all basic facts are known. The close links became obvious between pure and applied research in the study of the early life history of fish and of ichthyoplankton populations. Certain ichthyoplankton surveys, e.g., herring larval surveys in the North Sea, which were designed to answer specific questions for fisheries management, provide good basic data information on fish biology and biological oceanography. On the other hand, experiments on temperature tolerance have practical importance in view of thermal pollution. In studies of fish eggs and larvae ichthyologists, physiologists, ecologists and fishery biologists are collaborating closely.

Although ecology seems at present the focal point in most studies, many other aspects of the early life history stages of fish were discussed at the Symposium. Some recent achievements will be discussed with regard to their possible importance for future developments in ichthyoplankton research.

Morphology, systematics and taxonomy

Interest in environmental effects on vertebral counts has decreased of late. There is, however, much need for work on the histological and histochemical development of the brain and on the sensory, respiratory and digestive systems, if we want to understand changes in distribution, behaviour and feeding during the larval stage. Blaxter and his collaborators have produced valuable contributions in this field.

As shown by some of the systematic papers, fish larvae at hatching are at least as different as nestling birds. Later morphological adaptations are connected with feeding and distribution. Those adaptations, however, bring about lesser morphological differences than in adult fish. A comprehensive description of the fish larva in terms of functional morphology is still missing.

It is obvious that some species and families show systematic relationships much more clearly in the larval than in the adult phase. However, the general problem of identification of fish eggs and larvae has not been solved satisfactorily. Series of developmental stages are required to identify eggs and larvae, particularly in warm waters.

Physiological ecology

Physiological studies are still mainly concentrated on salmonids and clupeids and one wonders how far we can generalize those findings. Work on monofactorial tolerance and adaptation to changes in temperature, salinity, low oxygen level and other chemical factors is now considered important for the understanding of reactions of fish fry to environmental changes. Multifactorial experiments with proper mathematical design and analysis as carried out by Alderdice et al. make the important step from conventional comparative physiology to physiological ecology and should be applied to pollution studies. The work on possible effects of entrainments in power plants and of hydrogen sulphide are examples of the need for incorporating more than just one environmental factor in the analysis. Furthermore, it is now obvious that the various developmental stages show striking differences in their sensitivity to temperature, osmotic, chemical and mechanical stress. Adverse effects of harmful treatment of the mother fish on the viability of the eggs have been shown and similarly of sublethal harm to the eggs on the subsequent viability of the larvae.

Several field studies have confirmed the high mortality of fish eggs at sea. The causes of the mortality are largely unknown. Experiments show that it is unlikely that wave action and sunlight affect large parts of the egg production.

Starvation experiments are a special kind of physiological ecology study. They ask whether fish larvae in the sea are viable and whether they are approaching or have passed the "point of no return" (or the point of ecological death). Conditional factors are a somewhat doubtful measure; whether chemical analysis is a good substitute has still to be shown. Large-scale experiments on larval populations in plastic bags should be tried in which changes in size distribution and possibly in meristic characters can be analysed statistically. The problem of size hierarchies and pecking orders, with its relevance to feeding, was not dealt with in the Symposium but should receive some attention.

Feeding and predation

Starvation of fish larvae at sea has never been demonstrated beyond doubt, although available data on food demand versus food abundance suggest mass mortality by starvation. Additional food which is difficult to trace in the digestive canal, such as naked flagellates, detritus with bacteria and dissolved organic matter, has been suggested but rarely studied in a critical manner. Studies on stomach contents of larvae may not be

sufficient to describe the food intake of larvae at sea, while differences in rate and efficiency of digestion with type of food and with size of larvae have to be analysed. Without doubt, match and mismatch of food and larvae in space and time are vital. Any evaluation of food selection requires studies on relative vertical distribution of food organisms and larvae and of the increasing amplitude of their vertical migration with growth. Recent work on the importance of the surface layers as a feeding ground and refuge of certain kinds of fish larvae was mentioned in the discussion. The near-bottom layer might also call for some more attention. Vertical discontinuities in abundance of larvae and of food might be traced by the recent development of closing devices in front of the net and by pumps. On deck control of sampling depth and of changes in filtration due to clogging and sub-surface currents has become technically feasible. Horizontal patchiness, however, has not been satisfactorily studied.

Long-term observations show the relationship of egg and larval abundance with environmental conditions and provide some information on annual differences in mortality rates. Answers on interrelationships and trends in population dynamics and ecosystems will only be reached by a steady continuation of those programmes. Therefore, there is no question of the need for long observational series but there is room for further improvements in scientific and statistical design and in the sampling methods. Comparative tests on filtration rates and sampling capacity of various towed nets were reported and it again became obvious that both net avoidance and extrusion of larvae are largely dependent on towing speed and clogging. So far no net can sample all size categories of fish larvae in an entirely non-selective manner. The choice of gear therefore depends largely on the objectives of the programme. Bongo nets and the various types of Gulf III seem to be preferable in most cases as long as clogging does not reduce filtration, which is rather common for the encased Gulf III sampler during periods of high abundance of phytoplankton or coelenterates.

Predation is supposed to be one of the causes of mass mortality in fish eggs and larvae. Experimental studies on predation in larval anchovies by pontellids and euphausiids as summarized by Lasker are a start in a new field, which was opened up by the development of methods for the continuous production of eggs of some commercially important fish species as well as the controlled rearing of predators such as crustaceans, ctenophores, medusae and chaetognaths in the laboratory.

Aquaculture

Until recently, marine aquaculture of fish was largely based on wild fry, the larvae being fed with wild plankton or brine shrimp. During the past few years much work has been done to overcome the shortcomings of these methods and to make the cultivation and selective breeding of marine fish independent of the natural spawning and production cycles. The control of spawning by light and temperature permits egg production at any time of the year. The manufacturing of food particles and the mass culture of food organisms are prerequisites for successful continuous rearing of larvae. Brine shrimp is substituted by other more appropriate, easily digestible food organisms. In the discussion, Lasker reported on controlled spawning in anchovy and other species and several contributors demonstrated recent progress in fertilization and rearing of highly-priced fish, e.g., mullets, bass, sole and turbot. There are still many problems open for further work, particularly in the effect of dissolved organic substances, bacteria, viruses and parasites on the survival and development of fish larvae in mass culture. Studies of this kind would be also of interest for an interpretation of phenomena at sea.

Conclusions

The timing of spawning time in the seasonal production cycle of plankton is particularly evident in high latitudes. Synchronization of light, temperature, vertical stability and nutrient supply is not perfect in nature and spawning is not induced by them in just the same way as the production of planktonic food. Some mismatch should therefore be expected. Why is it that in high latitudes the spawning season of successful species is very short?

Why is the amplitude of year-class fluctuations low but still different by one or two orders of magnitude in ecologically and systematically closely-related species? Why can races of herring successfully reproduce in different seasons in one and the same area? The review by May on the "critical period" casts some doubt on the validity of any generalization with regard to population dynamics of fish larvae. It is not even certain that in all species regulation takes place at the larval stage.

In summary, a few major points should be listed which seem to require particular attention in the near future:

1) The high mortality of pelagic eggs in the sea

2) The possible patchiness of food organisms at sea and the reaction of larvae to those patches

3) Proofs of starvation and predation of larvae at sea

4) Importance of food which is difficult to trace and to identify in larval guts; digestion rates and digestion efficiency

5) Further gear development in order to reduce avoidance and extrusion and to improve control of sampling depth and filtration rate

6) Identification of fish eggs and larvae in tropical and subtropical waters and in the Southern Ocean

7) Multifactorial studies in physiological ecology, taking into account differences between species and developmental stages

8) Development of artificial encapsulated food for various kinds of larvae

9) Continuous production of eggs and larvae of more species under controlled conditions

10) Theoretical modelling based on actual knowledge of certain species and their ecological relationships.

The Symposium provided a good platform for the discussion of key problems in ichthyoplankton research. The thanks of all participants are due to the Sponsoring Organizations, the Steering Committee and particularly to the Local Organizers under the chairmanship of Dr. J.H.S. Blaxter.

ANNEX I

Speech Given by Sir Frederick Russell at Symposium Dinner

You have done me a great honour tonight, which I feel that I do not fully deserve. I may be the oldest of those present tonight but not the most leading in our field.

We may recall that it was in 1864 that G.O. Sars first brought to scientific notice the fact that cod, haddock and gurnards had pelagic eggs. But it was not until about 20 years later when the fear of damage by trawling was intense, that the study of the breeding of northwest European sea fishes was really started. Yet, in a short period of little more than ten years, the eggs and yolk-sac larval stages of nearly all the food fishes and many others had been described. This was chiefly the work of only four men: J.T. Cunningham, E. Ehrenbaum, E. Holt and W.C. McIntosh. As a result of this, it was possible for McIntosh and Masterman to produce their book on British Food Fishes in 1897, the year that I was born.

It is, perhaps, a measure of my own years that I have in my younger days actually seen both Cunningham and McIntosh at scientific meetings.

It was, however, not possible to complete these studies of life history until Petersen had invented his stramin young fish trawl by which post-larval stages could be caught in sufficient numbers to enable their description. This was seized on quickly by the Danes and the post-larvae and young of many fish were described in detail by Petersen and Johannes Schmidt by 1909; thus enabling Ehrenbaum to produce his invaluable Nordisches Plankton summary.

Since then, most of the gaps have been filled, although a few still remain.

I, myself, started to work in this field in 1922 when I was appointed to the Egyptian Government to study the eggs and larvae of fishes in the Eastern Mediterranean. Prior to going to Egypt, I was sent to Plymouth to receive training in methods of identification from R.S. Clark. After a year in Egypt I was appointed to the staff of the Plymouth laboratory to work on the problem of vertical distribution, although my interest widened into other spheres. I have kept my eyes on baby fish ever since.

Life in those early days was more simple. We were not burdened with the enormous widespread literature of modern times. Nomenclature too was more simple - we had, for instance, Clupea, Gadus, Onus, Pleuronectes and Solea, Blennius and Cottus - many species compressed into seven genera.

Today, I calculate that these same species are spread over something like 28 genera - four times as many. I am not implying that there has been a correlation between the multiplications of genera and the multiplications of workers. This has rather made me feel like the lady who, on paying a visit to a gentleman friend, was shown round his beautiful garden, taken from bed to bed and each flower, shrub and tree was pointed out and its specific name given. In saying goodbye, she said, thanking him for everything:

> "You are a very lucky man and how clever you are. Why? To know all these Latin names. I know only two - which are these. The first is Aurora borealis and the second is Delirium tremens."

But this multiplication of names has not hindered research if one bothers to look round this room and sees the multiplication of research workers.

For the pioneer descriptive work of the early scientists is now being put to good use. We are in a new era of research. Quite early on it was realized that studies on the numbers of eggs and larvae might throw light on the numbers of the adult populations. This was established between the wars by the investigations on the plaice spawning area in the southern North Sea by Buchanan Wollaston, to be later substantiated by Simpson. Surveys of larval populations are now done for a number of fish.

The more recent emphasis on the possibilities of rearing marine fish, fired off by Rollefsen in Norway and pioneered by Shelbourne have led to a desire to understand much more about the behaviour and physiology of larval fish. It is in this direction that most interesting advances are now being made through the remarkable studies by especially Blaxter, Hempel and Holliday. In this respect the Dunstaffnage Laboratory of the Scottish Marine Biological Association is noteworthy and it is fitting that this first International Symposium on the early life history of fish should be held here.

ANNEX II

List of Conveners and Steering Committee Members

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Dr. D.H. CUSHING - Population Studies
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ANNEX III

List of Papers Contributed

Author	Title
AHLSTROM, E.H.	The diverse patterns of metamorphosis in gonostomatid fishes - an aid to classification
BACHOP, W. and SCHWARTZ, F.J.	Quantitative nucleic acid histochemistry of the yolk sac syncytium of oviparous teleosts: implications for hypotheses of yolk utilization
BAINBRIDGE, V., COOPER, G.A. and HART, P.J.B.	Fluctuations in the abundance of the larvae of pelagic fish in European waters
BALAKRISHNAN, K.P.	Identification of fish larvae in a tropical estuary
BANNISTER, R.C.A., HARDING, D. and LOCKWOOD, S.J.	Larval mortality and subsequent year-class strength in the plaice
BARNABE, G.	Mass rearing of the bass Dicentrarchus labrax
BILLARD, R., PETIT, J. and JALABERT, B.	Sperm dilution in trout: An improvement in artificial insemination
BLAXTER, J.H.S. and EHRLICH, K.F.	Buoyancy and activity changes during growth and starvation of herring and plaice larvae
CUSHING, D.H.	Larval mortality and density dependence in fish
DICKSON, R.R., POPE, J.G. and HOLDEN, M.J.	Environmental influences on the survival of North Sea cod
DRAGESUND, O. and BJØRKE, H.	Efficiency tests on four high-speed plankton samplers
EHRLICH, K.F.	Chemical changes during growth and starvation of herring and plaice larvae
FLUCHTER, J.	Laboratory rearing of common sole (Solea solea L.) under controlled conditions at high density with low mortality
FONDS, M., ROSENTHAL, H. and ALDERDICE, D.F.	Influence of temperature and salinity on embryonic development, larval growth and vertebral number of garfish
GIRIN, M.	Nutrition of the larvae of turbot (Scophthalmus maximus (L.)) before metamorphosis
GJØSAETER, J. and SAETRE, R.	Use of egg and larval data for estimating spawning stock of fish with demersal eggs
HART, P.J.B.	Long-term changes in the distribution and abundance of larval sand eels in the North Sea and their relationship to planktonic and hydrographic events
HOAGMAN, W.J.	Vital activity parameters in larval and post-larval whitefish
HOKANSON, K.E.F. and KLEINER, C.F.	Effects of constant and rising temperatures on development and survival of embryos and larvae of yellow perch
HOSS, D.E., HETTLER, W.F. Jr. and COSTON, L.C.	Effects of thermal shock on larval estuarine fish - ecological implications with respect to entrainment in power plant cooling systems

HUBBS, C. and BRYAN, C.	Effect of parental temperature experience on thermal tolerance of eggs of Menidia audens
HUNTER, J.R. and THOMAS, G.	Effect of prey distribution and density on the searching and feeding behaviour of larval anchovy
IRVIN, D.N.	Temperature tolerance in early developmental stages of Dover sole
ISHIBASHI, N.	Feeding, starvation and weight changes of early fish larvae
JONES, A., ALDERSON, R. and HOWEL, B.R.	Progress toward the development of a successful rearing technique for larvae of the turbot (Scophthalmus maximus L.)
JONES, R. and HALL, W.B.	Observations on the population dynamics of the larval stage in common gadoids
KHAN, N.Y. and FABER, D.J.	A comparison of larvae of freshwater and estuarine sculpin, Myoxocephalus quadricornis L., from North America. I. Morphological Development
MARAK, R.R.	Food and feeding of larval redfish in the Gulf of Maine
MATSUURA, Y.	Morphological and ecological studies of clupeoid larvae from Southern Brazil
MAY, R.C.	Larval mortality in marine fishes and the "critical period" concept
DE MENDIOLA, B.R.	The food of the larval anchoveta
MEYER-ROCHOW, V.B.	Behaviour and structure of the larval sense organs in a deep-sea fish (Cataetyx memorabilis)
MILLER, J.M.	Distribution patterns of Hawaiian fish larvae: effects of currents and water quality
MOSER, G.H. and AHLSTROM, E.H.	The role of larval stages in systematic investigations of marine teleosts: The Myctophidae, a case study
NELLEN, W.	Investigation on the distribution of fish larvae and plankton near and above the Great Meteor Seamount
OKIYAMA, M.	The larval taxonomy of primitive myctophiform fishes
PACKARD, A. and WAINWRIGHT, A.W.	Brain dimension and growth stage
PETER, K.J.	Seasonal variation of ichthyoplankton in the Arabian Sea with respect to the monsoon
PINUS, G.N.	Some factors influencing early survival and abundance of Clupeonella in the Sea of Azov
POMMERANZ, T.	Resistance of plaice eggs to mechanical stress and light
POSTUMA, K.H. and ZIJLSTRA, J.J.	Larval abundance in relation to stock size, spawning potential and recruitment in North Sea herring
POWLES, P.M.	Survival of Australian anchovy eggs and larvae in a heat trap
PURDOM, C.E. and LINCOLN, R.F.	Gynogenesis in 'Hybrids' within the Pleuronectidae
RENE, F.	Rearing of gilt-head Sparus aurata
RICE, S.D. and STOKES, R.M.	Nitrogen waste product metabolism in the eggs and fry of rainbow trout

RICHARDS, W.J. and POTTHOFF, T.	Analysis of the taxonomic characters of young scombrid and istiophorid fishes
RILEY, J.D.	Distribution and mortality of sole (Solea solea (L)) eggs in inshore areas
ROSENTHAL, H. and SPERLING, K.-R.	Effects of cadmium on development and survival of herring eggs
SAVILLE, A., BAXTER, I.G. and McKAY, D.W.	Relations between egg production, larval production and spawning stock size in Clyde herring
SCHNACK, D.	On the reliability of methods for quantitative sampling of fish larvae
SELIVEZTOV, A.S.	Vertical migration of Atlanto-Scandian herring larvae
SIEFERT, R.E., SPOOR, W.A. and CARLSON, A.R.	Effects of depressed dissolved oxygen concentrations on embryos and larvae of some freshwater fishes
DE SILVA, C. and TYTLER, P.	Development of the respiratory system in herring and plaice larvae
SMITH, L.L. Jr.	Effect of temperature and hydrogen sulphide on development and survival of five freshwater fish species
SOUTHWARD, A.J. and DEMIR, N.	Seasonal changes in the dimensions and viability of pilchard eggs
STANLEY, J.G. and SNEED, K.E.	Artificial gynogenesis and its application in genetics and selective breeding of fishes
TANAKA, S.	Significance of egg and larval surveys in the study of population dynamics of fishes
THEILACKER, G.H. and LASKER, R.	Laboratory studies of predation by euphausiids on fish larvae
UEYANAGI, S.	Present state of billfish larvae taxonomy
WILLIAMS, R. and HART, P.J.B.	The vertical and seasonal distribution of fish eggs and larvae at ocean weather station "India" in relation to the biological and physical oceanography of the area
WILSON, K.W.	The ability of herring and plaice larvae to avoid concentrations of oil dispersants
WYATT, T.	The feeding of fish larvae in the Southern Bight of the North Sea in relation to the distribution of food organisms
YUSA, T.	Early life history of Limanda yokohamae (Günther)

ANNEX IV

Abstracts of Papers

THE DIVERSE PATTERNS OF METAMORPHOSIS IN GONOSTOMATID FISHES - AN AID TO CLASSIFICATION

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Gonostomatid fishes rank next to myctophid lanternfishes as the most numerous fishes in the oceanic realm in temperate to tropical waters. Larvae of gonostomatids usually constitute 20 to 25 percent of the fish larvae taken in offshore oceanic waters of all oceans, with two genera dominating, Vinciguerria and Cyclothone. The family contains circa 20 genera and 60 species. Larvae of eleven genera have been obtained from the eastern Pacific, and larvae or transforming specimens of four additional genera have been described - hence development is known for three quarters of the genera.

The patterns of photophore development during the larval and metamorphic stages, together with specializations in photophore groups in adults, constitute the most trenchant characters for showing relationships among genera and species of gonostomatids.

In some genera, e.g., Vinciguerria and Cyclothone, most photophores form simultaneously during a white photophore stage. More commonly, most ventral photophores form as white photophores, but the lateral photophores form later and usually gradually, e.g., in Ichthyococcus, Polymetme, Pollichthys and Diplophos. All the above genera have individual photophores. Three genera with individual photophores - Gonostoma, Bonapartia and Margrethia - usually have a protracted metamorphosis. Gonostoma appears to be the pivotal genus with respect to photophore development; among species of Gonostoma, photophores may be formed gradually over a rather extended size range as in G. elongatum or G. denudatum, or fairly rapidly as in G. fragilis and G. atlanticum. The former are closely allied in development to Bonapartia and Margrethia - as well as to the maurolicine and sternoptychid genera. The subopercular pair of photophores is the first to form in all six species of Gonostoma as well as in Margrethia and Bonapartia. The next photophores to form are in the PV series, but otherwise the sequence is various as among species.

Maurolicus and related genera, Valenciennellus, Danaphos, Araiophos and Argyripnus, have a protracted metamorphosis with gradual formation of photophores. In the maurolicine genera most photophores occur in clusters with common bases, rather than as separate photophores. The developmental pattern shared in common by all maurolicine genera, for which early metamorphic stage specimens are known, is the initial formation of photophores in the Br and PV groups.

The sternoptychid genus, Sternoptyx, develops the subopercular pair of photophores first, soon followed by Br, PV and IP photophores; as in maurolicine larvae, sternoptychid larvae have a protracted metamorphic stage and clustered photophores. The maurolicine genera are as closely related to sternoptychids as to the other genera of gonostomatids, hence it is suggested that the gonostomatid and sternoptychid genera be combined into one family, the Sternoptychidae. Within the family the genera with clustered photophores could be separated as the subfamily Sternoptychinae, those with single photophores as the subfamily Gonostomatinae. Both subfamilies could be further subdivided into tribes.

QUANTITATIVE NUCLEIC ACID HISTOCHEMISTRY OF THE YOLK SAC SYNCYTIUM OF OVIPAROUS TELEOSTS: IMPLICATIONS FOR HYPOTHESES OF YOLK UTILIZATION

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The yolk of the embryo of an oviparous teleost is completely enclosed within a syncytium that differs from syncytia in other vertebrates in that many, if not all, of its nuclei become giants. These giant nuclei are found by Feulgen microphotometry and scanning microdensitometry to contain amounts of DNA far in excess of the amount found in nuclei of diploid cells of the same embryo. Study of the mode of formation of these giant nuclei shows that excess DNA is compartmentalized in the form of extra sets of chromosomes per nucleus (polyploidy) without apparent increase in amount of DNA per chromosome. The presence of giant polyploid nuclei in the syncytium subserving yolk resorption in oviparous teleosts suggests that biochemical hypotheses of teleostean yolk resorption, predicated on the mistaken assumption that yolk is resorbed from the lumen of the embryonic gut through a layer of endodermal cells containing small diploid nuclei, should be replaced by hypotheses that (i) accord with the topographic and microscopic anatomy of the yolk sac of oviparous teleosts, and (ii) ascribe a functional role to polyploidy and syncytialization in these embryos.

FLUCTUATIONS IN THE ABUNDANCE OF THE LARVAE OF PELAGIC FISH IN EUROPEAN WATERS

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The Continuous Plankton Recorder Survey provides the opportunity for studies on the ecology of fish larvae over a wide area.

All major stocks of herring can be distinguished from the geographical and seasonal distribution of their early larvae. There appears to be a single population of mackerel in the North Sea, and another to the west of the British Isles. Blue whiting, spawning over Rockall and Porcupine Banks, may represent a single population.

The spawning of pelagic fish stocks in oceanic and transitional areas is closely associated with the biological spring, when food for the larvae is most plentiful. This may not hold true in neritic areas where plankton development is more regular, and less restricted, seasonally.

Among several distinctive long-term trends are the decreasing numbers of herring larvae off the Norwegian coast and in the southern North Sea, reflecting declining stocks; an increase in the numbers of mackerel larvae in the North Sea during the fifties, and a southerly swing in the distribution of the blue whiting larvae during the sixties. Possible links between natural changes in larval populations and plankton production cycles are considered.

IDENTIFICATION OF FISH LARVAE IN A TROPICAL ESTUARY

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Larvae of Soleidae and Cynoglossidae are the only groups of flat fishes (Heterosomata) occurring in the Cochin Backwater (a tropical estuary). Developmental stages of Solea heinii (Steindachner), C. puncticeps (Richardson), C. brevis (Günther), C. cynoglossus (Ham. Buch) and C. lida (Bleeker) are found in the plankton. The diagnostic characters which are helpful in identifying the larvae of different species are the elongated rays at the anterior end of the dorsal fin fold, cartilaginous structures connected with the fins, sequence of development of fin complements and ossification of various parts of the supporting skeleton, the number of vertebrae and fin rays, nature and distribution of pigments and shape and consistency of the body.

LARVAL MORTALITY AND SUBSEQUENT YEAR-CLASS STRENGTH IN THE PLAICE

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Most marine fish of commercial importance have extremely high fecundities and the correspondingly high mortalities known to occur during the early part of their life cycles, particularly during the pelagic egg and larval phase, must be part of the natural process of maintaining the populations in balance. Hjort (1914) was the first to suggest that good and bad year-classes may be determined during this pelagic phase.

These investigations use data collected from several sources to illustrate the life history of the plaice in numerical terms. The pelagic phase has been described from surveys of known spawning grounds using high-speed plankton samplers. Nursery grounds where 0 and 1 group fish live were sampled with push nets and beam trawls; while information on adult stocks was obtained mainly from the market sampling of landings by commercial trawlers.

Larval abundance and mortality estimates in the southern North Sea spawnings have been correlated with subsequent year-class strengths in the English plaice landings and give credence to Hjort's original hypothesis. In particular the high survival of the 1963 year class has been shown to be of utmost importance; for catch, effort and price statistics and age composition data show very clearly that the recruitment of 1963 year-class to the fisheries has been a major factor in the recent exceptional landings of North Sea plaice by Denmark, the Netherlands and the U.K.

MASS REARING OF THE BASS Dicentrarchus labrax

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Maturing females, after a hormone injection, are placed in a tank of 2.5 m^3 with naturally running males. They then spawn viable eggs which the males fertilize normally. The pelagic eggs are collected and incubated in illuminated still water at salinity of 34.5‰ and temperature of 15° C in which planktonic algae ('green water') had previously been cultured.

Hatching occurs after 70 hours. Two days after hatching, the rotifer Brachionus plicatilis, separately cultured, is introduced into the medium. The best results are obtained with a rearing density of about 5 rotifers/ml. The rotifers can be replaced by the ciliate Fabrea salina. Five days later the density can be reduced to 1/ml. From the 12th day, nauplii of Artemia salina are provided alternately with the rotifers. A diet of only Artemia for several days proved to be inadequate as food. From the 15th to 35th day Artemia are given alternately with specimens collected with plankton hauls (mainly the copepod Eurytemora velox). From the 30th day to the end of the experiment the food consists of minced fish and crab.

In 5 circular tanks each of 7.8 m^3 and consisting of a plastic liner inside a plywood cylinder, 45 000 alevins were produced.

SPERM DILUTION IN TROUT: AN IMPROVEMENT IN ARTIFICIAL INSEMINATION

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A new technique of artificial insemination has been performed on rainbow trout using a diluant for milt. The best diluent was a saline solution with an osmotic pressure of 255 milliosmols (about 10 g NaCl/l distilled water) buffered at pH 9.5 with carbonate-bicarbonate or Tris buffers. The timing for mixing of gametes and diluent was also very important and will be discussed. The dilution limit ranged between 10^{-3} to 10^{-4} and the minimum number of spermatozoa required to fertilize one egg varied from 50 000 to 200 000. It is theoretically possible therefore to inseminate several hundred females with the sperm of just one male.

BUOYANCY AND ACTIVITY CHANGES DURING GROWTH AND STARVATION OF HERRING AND PLAICE LARVAE

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The sinking rate of herring larvae in sea water (10°C, 33 per mille) decreased from 0.407 cm/sec at hatching to 0.225 cm/sec at the end of the yolk-sac stage. In feeding larvae the sinking rate then increased to 1.54 cm/sec by 25 mm in length. Newly hatched plaice larvae were positively buoyant, but their sinking rate increased to 0.185 cm/sec by the end of the yolk-sac stage. The rate continued to increase during growth and development, reaching 1.120 cm/sec by 38 days. In both species the sinking rate decreased during starvation. It was suggested that this is a mechanism of energy conservation. The changes in sinking rate from hatching between the species were related to habitat differences and behavioural changes during ontogenesis.

Water content was inversely related to the sinking rate, but other body components also influenced it. The forces contributing to the sinking rate from fat, carbohydrate and protein, as well as water were computed during starvation, from the end of the yolk-sac stage for both herring and plaice. In both species water provided the major upward vector, followed by fat, while protein was responsible for the downward force. The decrease in sinking rate during starvation was partially due to the increasing percentage of water, although the major part of the decrease resulted from nitrogen catabolism throughout starvation.

The activity of herring and plaice larvae in the first few weeks of life was monitored by a thermistor technique in a vertical migration apparatus. A normal pattern of vertical migration in fed larvae was established using both natural and artificial light cycles. The progressive breakdown of this pattern was then determined in larvae starved for varying periods of time.

LARVAL MORTALITY AND DENSITY DEPENDENCE IN FISH

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The natural mortality of fishes is probably generated by predation; the ultimate cause of death may sometimes be a parasite or a disease, but the proximate cause is predation. There are two parts to predation, the time to handle and eat, and the time to search. The latter is inversely density-dependent, and so natural mortality is also. During their life cycles, fish grow through a series of predatory fields. Growth is a function of age and so natural mortality may be expressed as a density-dependent function of age.

The larval mortality of plaice has been well established. With a formulation of natural mortality as a function of age, the adult mortality can be expressed from the larval mortality. Further, variability in the larval and O-group mortality (as functions of growth) probably generate the regulatory function of the population.

ENVIRONMENTAL INFLUENCES ON THE SURVIVAL OF NORTH SEA COD

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In general, year-class size of cod shows a positive relationship with temperature at the poleward limits of its range and a negative relationship at its equatorward limit. The recent cooling tendency of the North Sea, where cod is near the southward limits of its range, has been associated with an increase in year-class size. Critical statistical analyses of multi-year sea temperature data for the Hull-Hanstolm and Leith-Bremen sampling routes, which cover some of the most important cod spawning grounds of the central North Sea, and indices of cod recruitment show significantly high negative correlations between year-class size and the sea surface temperatures from January to May, the period of spawning and larval drift. The relationship is most consistently high in January and April, and to a lesser extent in May. The mechanisms by which low temperatures could increase high survival are discussed and it is suggested that they operate by maximizing the proportion of eggs which hatch by enhancing the chance of a match between hatching and production and by optimizing the metabolic range of the species.

EFFICIENCY TESTS ON FOUR HIGH-SPEED PLANKTON SAMPLERS

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Comparisons were made of the catching efficiencies for capelin larvae in 1971 and 1972 of four high-speed plankton samplers, viz: a BCF Bongo .03 (B20, ø 20 cm), a Hydrobios Bongo (B60, ø 60 cm), a Clarke-Bumpus plankton sampler (CB ø 12.5 cm) and a Dutch version of Gulf III (DG III, ø 20 cm).

In 1972 two types of hauls were made alternating with each other six times:

1. The B20, the B60 and the CB were attached to the same wire 3m apart, and towed at 3 knots
2. The DG III sampler was towed separately at 5 knots.

In 1971 each of the gears was towed separately nine times in random succession. Both in 1971 and 1972 the tows were double oblique hauls with a maximum depth of 30 m, the distance towed being approximately 1 200 metres.

The test on the 1972 material showed that the number of larvae caught with DG III was significantly larger than those caught with the other gears. The catches of the B20 and CB were the smallest. In the 1971 material the number of hauls were too few to show significant differences between the gears. However, the results from this test support the results obtained in 1972.

When comparing the number of larvae and the volume of plankton caught with the different gears in 1972, it is concluded that the larvae seemed to avoid the B20 and B60 more than the DG III. Both larvae and plankton seemed to avoid the CB sampler. Examination of the length frequency distribution of larvae could not explain this avoidance. The length of the larvae varied between 6 and 16 millimetres.

CHEMICAL CHANGES DURING GROWTH AND STARVATION OF HERRING LARVAE

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Changes in water, triglyceride, carbohydrate, nitrogen, carbon and ash were followed during ontogenesis, from the end of the yolk-sac stage through metamorphosis, as well as during starvation of various larval size groups. Ontogenetic changes were dependent upon larval size rather than age. Throughout development from the end of the yolk-sac stage to metamorphosis, the percentage of water decreased continuously, from about 89 to about 82 percent. In the period of initial post-hatching growth (up to 20 mm in herring) nitrogen and carbohydrate were laid down faster than triglyceride. The pattern was then altered in larger larvae. It was suggested that the initial preferential deposition of protein to triglyceride was advantageous to the larvae in that it enabled them to put on growth more quickly than if they had been simultaneously accumulating energy stores. This increased the size range of foods available to them and hence their chances of survival.

During starvation the percentage of water increased about 4 percent above the unstarved level. The percentage of triglyceride, carbohydrate and carbon decreased. However, the percentage of nitrogen did not change throughout starvation, although the actual amount decreased. Percent ash increased rapidly during starvation. The C/N ratio decreased in starved animals. A striking feature throughout starvation was the continuous depletion of nitrogen. It was suggested that since nitrogen catabolism was responsible for the decreasing sinking rate of the larvae during starvation, this unusually high rate of use could be an adaptation by pelagic marine fish larvae to the planktonic environment.

LABORATORY REARING OF COMMON SOLE (*Solea solea* L.) UNDER CONTROLLED CONDITIONS AT HIGH DENSITY WITH LOW MORTALITY

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The results of previous rearing experiments gave the impression that survival rate of sole fry is closely connected with the presence of certain ciliates. Starting from the idea that when rearing the larvae, the complete satisfying of the requirements for larval life should lead to a survival rate of almost 100 percent, it was supposed that the larvae needed organisms of this kind obligatorily as their first food.

To bring this factor under control, the larvae were transferred into sterile, filtered sea water. Small jars (1 l or less) were used where the presence or absence of microfauna could be better controlled. Different species of protozoans suspected of being the first food were then offered from pure cultures. Pure sterile, filtered sea water was used as a control.

The surprising result of these rearing experiments is as follows:

The survival of sole larvae when starting feeding (on Artemia nauplii) is dependent on the presence of a dissolved organic substance of algal or bacterial origin. The effectiveness of this substance is not reduced by ageing the sea water or by autoclaving at 110°C. Small crustaceans can extract this substance from the sea water.

A survival rate of more than 95 percent at a density of max. 200 larvae per litre could be obtained. Exact data about the life requirements, especially from hatching up to metamorphosis, are given. These are necessary as a basis for further experiments, especially aimed at the question of whether fish larvae obligatorily have to absorb a dissolved organic substance from the sea water.

The adult soles could be induced to spawn spontaneously even in very small containers, by using a special kind of forcible feeding.

INFLUENCE OF TEMPERATURE AND SALINITY ON EMBRYONIC DEVELOPMENT LARVAL GROWTH AND VERTEBRAL NUMBER OF GARFISH

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Eggs of the garfish (Belone belone) were incubated at 13 different salinity-temperature combinations (range: 10–45 per mille S; 9–24°C). Data were collected on rate of embryonic development, survival to hatching and larval size. The larvae were reared at the same incubation conditions to a total length of about 3 cm for measurement of growth and number of vertebrae. Salinity-temperature conditions were estimated, associated with maxima or minima of some of the measured attributes. Incubation time from fertilization to mean hatching time, ranged between 866 h at 13.2°C and 240 h at 24°C. Survival of eggs and larvae was maximized at 17.4 to 19.4°C and 31 to 37 per mille S. Size of newly hatched larvae decreased with increasing incubation temperatures and salinities; yolk-sac size was inversely correlated with body size. Embryonic growth (mm/day) and growth of larvae (mm/day) showed a linear increase with temperature. Growth of the reared fish in mg/day showed an exponential increase with temperature. Mean vertebral number reached a minimum at 21.2°C and 41.1 per mille S. Vertebral numbers were mainly affected by temperature. Survival of garfish eggs and larvae at a wide range of temperature and salinity is probably related to the coastal spawning habit of the species. However, Belone belone cannot be considered as an estuarine species.

NUTRITION OF THE LARVAE OF TURBOT (Scophthalmus maximus (L.)) BEFORE METAMORPHOSIS

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The intention of the experiment was to determine the quantitative food requirements for turbot larvae (Scophthalmus maximus L.) fed with the rotifer Brachionus plicatilis (which were fed with Tetraselmis suecica) and the nauplii of the crustacean branchiopod Artemia salina. The observations were made from hatching to the 20th day, the critical phase of metamorphosis at the temperature used. The seven aquaria used, all identical, had translucent sides. They contained 50 l of water, maintained at 21 °C, renewed by a tenth each day. A classical aquarium diffuser provided slight movement of the water. The larvae were introduced the day after hatching at concentrations varying between 15 and 50 per litre. They originated from an artificial spawning, some eggs having been incubated in baskets and others in strongly aerated troughs. The Brachionus were added the next day at concentrations between 10 and 50 per ml for seven to nine days, the Artemia from the fifth to seventh day and up to the end of the experiment.

The dead larvae were taken out every day and the survival curves from the different lots compared. The best of them showed a survival of 20 percent at the end of the experiment, in relation to the number of larvae living the day after hatching. The concentration of food organisms was about 30 Brachionus per ml (the second day). Following this the number of food organisms offered per living larva per day was 150 rotifers from the second to the tenth day and 190 nauplii of Artemia from the sixth to the nineteenth day.

USE OF EGG AND LARVAL DATA FOR ESTIMATING SPAWNING STOCK OF FISH WITH DEMERSAL EGGS

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This paper gives a brief review of the established methods for estimating spawning stock size based on observations of spawning products. Factors influencing these estimates are discussed.

Two new methods for estimating the size of the spawning stock for fish with demersal eggs are described. Both methods assume that the hatching curve is known, and only newly hatched larvae are used. In the first method the number of eggs deposited at one of the spawning beds is determined. After hatching has started an abundance index for young larvae released from this spawning bed has to be obtained, and referred to a known point at the hatching curve. The ratio between number of eggs and this index, together with the hatching curves and larval abundance index for the whole spawning area are used for estimating the spawning stock size.

In the second method, the hatching curve is used for calculating the percentage of eggs that are hatched at any time. On the assumption that the number of newly hatched larvae sampled corresponds to this percentage, the size of the spawning stock may be found.

The usefulness of these methods is discussed and they are applied on the Barents Sea capelin in 1971 and 1972. The estimates obtained are fairly similar to those obtained by other methods.

LONG TERM CHANGES IN THE DISTRIBUTION AND ABUNDANCE OF LARVAL SAND EELS IN THE NORTH SEA AND THEIR RELATIONSHIP TO PLANKTONIC AND HYDROGRAPHIC EVENTS

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The distribution of larval Ammodytes marinus (Raitt) in the North Sea was determined using data obtained from Continuous Plankton Records taken between 1948 and 1968. The data were divided into seven subareas, the limits of each being determined from the frequency of larval occurrence along each Recorder route. This distribution was then examined in relation to hydrographical features. For each area and year the mean numbers of larvae per sample were calculated. The pattern of annual fluctuations in abundance between the seven sub-areas was examined for between-area trends or correlations with events in adult population and recent hydrographic changes in the North Sea.

VITAL ACTIVITY PARAMETERS IN LARVAL AND POST-LARVAL WHITEFISH

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Larvae lake whitefish hatched in nature were transported to constant environmental conditions and experimented on over fish sizes of 12.6 to 24.9 millimetres. Swimming speed while feeding on live plankton was 1.5 cm/sec and did not increase proportional to size; but sustained swimming ability increased from 3.7 to 11.4 cm/sec and maximum short distance speed increased from 6.7 to 22.6 cm/second. Body lengths per second remained nearly constant, averaging 3.7 times the body length. The overall relationship between speed and length was $L^{\cdot 68}$ for sustained and $L^{\cdot 91}$ for maximum speed.

The young whitefish were non-schooling and fed independently. The effective feeding rate on copepods was 37.8 percent of all encounters and feeding ceased during absolute darkness while continuing at moonlight levels. Food intake and activity were continuous enabling the larvae to search between 8.1 l/h and 13.5 l/hour. From other tests and observations including digestion rate and starvation time, natural death due to starvation in nature is extremely remote.

Whitefish larvae preferred temperatures between 12–17°C when acclimated at 6, 11 and 14.5°C before testing. Direct avoidance occurred at 20–23°C, and heat narcosis and death above 24°C. No change in temperature preference was apparent with increase in size. Light gradients from 230 to 0.1 foot candles had no concentrating effects except at the smallest sizes. Beyond 14 mm total length the larvae ignored differences in light intensity.

Vertical distribution in the laboratory was epipelagic, confirming catches of 95 percent in the top metre in nature. Negative buoyancy required constant swimming to remain neutral until filling of the air bladder at larger sizes.

EFFECTS OF CONSTANT AND RISING TEMPERATURES ON DEVELOPMENT AND SURVIVAL OF EMBRYOS AND LARVAE OF YELLOW PERCH

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The survival and duration of development of yellow perch (Perca flavescens (Mitchill)) embryos and larvae were studied in continuous-flow incubators at constant temperatures ranging from 3.0 to 25.5°C. Eggs were tempered to test conditions either soon after fertilization, or after the neural keel had been formed in embryos held at 12.0°C. A portion of the embryos, reared initially at 5, 7 and 10°C, were exposed to rising temperatures at an average rate of increase of 0.5 or 1.0°C/day. At constant incubation temperatures, the lower and upper median tolerance limits (TL50) were 6.8 and 19.9°C for normal hatch, and 9.8 and 18.8°C for yield of free-swimming larvae. The optimum range was quite narrow (13.0-16.1°C). The TL50 limits for embryos tempered to temperature extremes after formation of the neural keel were 7.0 and 22.9°C for normal hatch, and 9.3 and 22.5°C for yield of free-swimming larvae. Under rising temperature regimes the yield of free-swimming larvae was highest while the incidence of abnormalities and duration of the hatching period were lowest. The average time to mass hatch ranged from 6 days at 19.7°C to 51 days at 5.4°C. Hatching was precocious at 5.4 and 3.1°C. The larvae became free-swimming within two days after mass hatch above 7.3°C. Median survival time of unfed larvae ranged from 15 days at 19.8°C to 65 days at 5.3°C.

EFFECTS OF THERMAL SHOCK ON LARVAL ESTUARINE FISH - ECOLOGICAL IMPLICATIONS WITH RESPECT TO ENTRAINMENT IN POWER PLANT COOLING SYSTEMS

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Critical thermal maximum (CTM), oxygen consumption, survival, and behaviour of larval fish were examined as a function of magnitude of temperature change, exposure time and salinity for larvae of Atlantic menhaden (Brevoortia tyrannus), spot (Leiostomus xanthurus), pinfish (Lagodon rhomboides) and three species of flounder (Paralichthys spp.).

Measurements of CTM were inadequate for evaluating the effects of entrainment on larval fish, although they were useful in establishing ranges of thermal tolerance. Oxygen consumption of larval fish responded quickly to thermal shock, response being dependent on magnitude and direction of temperature change. Survival was related to magnitude of temperature change, length of exposure, salinity and species. Observations on behaviour of the experimental fish indicated that at least two shocks were discernible during entrainment: one when the fish passed from environmental temperature to the entrainment temperature and a second when the fish returned to the environmental temperature. Results are discussed in relation to the possible effects of entrainment on larval fish production in estuarine waters.

EFFECT OF PARENTAL TEMPERATURE EXPERIENCE ON THERMAL TOLERANCE OF EGGS OF *Menidia audens*

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Thermal tolerance of eggs of the silverside, *Menidia audens*, is shown to be influenced by prior temperature experience of the parent. A 9 deg C difference in parental acclimation temperature resulted in an upward shift in thermal tolerance of eggs from the higher of two parental acclimation groups. This shift, measured in terms of the thermal range at which gastrulation would occur, was of the order of 1 deg C. However, a reversal occurred when the thermal stress, used to define the range, was maintained after gastrulation. That is, the thermal tolerance range of eggs from the higher parental temperature acclimation was displaced downward by about 2 deg C in comparison with the range obtained for eggs from the lower parental acclimation group. This phenomenon is not likely to involve temperature shock; eggs exposed to sublethal thermal stresses and returned to optimal temperatures showed high survival, despite being subjected to two thermal shocks in such transfers.

EFFECT OF PREY DISTRIBUTION AND DENSITY ON THE SEARCHING AND FEEDING BEHAVIOUR OF LARVAL ANCHOVY

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Searching and feeding behaviour of larval anchovy (*Engraulis mordax*) was studied when prey were highly aggregated and at various densities when prey were not highly aggregated. They prey used in most experiments was the dinoflagellate, *Gymnodinium splendens*; the rotifer, *Brachionus plicatilis*, and the copepod, *Tisbe furcata* were used in comparative studies.

Yolk-sac and post yolk-sac larvae found and remained in patches of *Gymnodinium* in the day and at night. Attraction of larvae to a patch was a function of the density and volume of the patch. The structure of searching behaviour at various prey densities was analysed by recording movements of larvae as they swam over a grid. Speed and direction of search patterns of larval anchovy were density-dependent. Larvae swam faster at low prey densities than they did at higher ones. The expected area covered by a larva on the basis of directional characteristics alone was greater at low prey densities than at higher ones. No difference existed in either speed or directional characteristics of search patterns between larvae fed *Gymnodinium* and those fed *Brachionus* or *Tisbe*.

TEMPERATURE TOLERANCE IN EARLY DEVELOPMENTAL STAGES OF DOVER SOLE

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Aspects of temperature tolerance were investigated in successive developmental stages of S. solea, including the egg, yolk-sac larva, feeding larva and larvae at metamorphosis. Eggs incubated at constant temperatures within a defined zone of temperature tolerance showed equivalent survival over five-day periods of exposure. However, continued exposure yielded a significant relation between all such temperatures and time to 50 percent mortality. Upper and lower lethal temperature limits (96 h LD50) were estimated for larval stages. Temperature tolerance increased during development up to metamorphosis at which point it corresponded closely with that of juvenile fish.

FEEDING, STARVATION AND WEIGHT CHANGES OF EARLY FISH LARVAE

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After hatching the body weight of the pre-larval stages of Tilapia sparmanii (a tropical freshwater fish with attached eggs) and Paralichthys olivaceus (a marine flatfish with pelagic eggs) increases until the yolk disappears. They lose weight if no food is taken. Feeding commences before the yolk is fully resorbed and before the jaws and gut are fully developed.

The weight increase after hatching in Tilapia is due to uptake of water. The rate of increase of oxygen consumption does not change until the point of maximum weight on the yolk is reached. High temperatures accelerate the time to first feeding but do not influence the maximum weight reached on the yolk supply.

PROGRESS TOWARD THE DEVELOPMENT OF A SUCCESSFUL REARING TECHNIQUE FOR LARVAE OF THE TURBOT (Scophthalmus maximus L.)

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The turbot (Scophthalmus maximus L.), by virtue of its fast growth rate and high market price, is an attractive species for commercial cultivation. During the summer of 1972 approximately 100 larvae of this species were successfully reared through metamorphosis for the first time at the MAFF laboratories at Lowestoft and Port Erin.

Eggs, obtained at sea from wild fish and from laboratory stock, were fertilized artificially and incubated within the temperature range 10-14 °C. Larvae hatched after nine days at 10 °C and five days at 14 °C measuring approximately 3.0 mm in length. Rearing was done at temperatures between 15 °C and 18 °C. The larvae were fed initially on the marine rotifer Brachionus plicatilis, Muller, followed by Artemia nauplii 12-14 days after hatching.

From day 30 larvae were offered Artemia metanauplii and adult Artemia. Metamorphosis was completed between 45 and 80 days from hatching, when the larvae ranged in length from 23 to 32 millimetres. After metamorphosis the fish readily took to a diet of chopped ragworm (Nereis diversicolor), and subsequently a compounded diet based on minced trash fish. Survival to metamorphosis was low; however, in one experiment survival from seven days after hatching to metamorphosis reached 10 percent.

OBSERVATIONS ON THE POPULATION DYNAMICS OF THE LARVAL STAGE IN COMMON GADOIDS

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The authors have shown in two previous papers that a larval model based on the idea that food density is critical for survival during the larval stage can explain much that is known about the early life history of fish such as haddock and cod. In particular, the model has been able:

a) to account for high larval mortality rates of about 10 percent per day;

b) to explain how control of population numbers might be effected in the common gadoids;

c) to account for population control independently in species that spawn successively in the same area;

d) to show that the maximum numbers of survivors ought to occur when the number of larvae per cohort at the commencement of feeding, is between 10^8 and 10^9 per square mile. The The significance of this is that estimates for a number of fish species fall within this range;

e) to account for variations in year-class strengths of the magnitude observed in North Sea haddock and whiting, by assuming annual variations in larval food of a not unreasonable magnitude.

One characteristic of the feeding of haddock and cod larvae is that they appear to feed on the young growing stages of their food species, giving an impression of cohorts of fish larvae growing up with cohorts of food organisms. In such a situation there would appear to be a choice of feeding strategies. By eating only the largest organisms which it is capable of ingesting, a larva could minimize the number of organisms needed per day, but only at the expense of reducing the availability of suitable food. Alternatively, it could increase the density of suitable food by eating smaller organisms also, but only at the expense of increasing the number required per day. In practice, feeding strategy is likely to be a compromise between these alternatives of particular interest is the range of sizes of food organisms when feeding commences. This will presumably influence larval size at the commencement of feeding and hence could be a factor in determining egg size (and hence indirectly in determining fecundity).

Extensive simulation of the effects of competition between genotypes with different feeding strategies has suggested that species like the haddock ought to be able to maximize its chance of survival by eating juvenile copepods born within a 5-20 day period. This result appears to be reasonably consistent with the size range of copepods such as Calanus actually found in gadoid stomachs at the commencement of feeding.

It is concluded therefore that a food limiting model of the kind referred to in the paper is able to account quantitatively, as well as qualitatively, for much that is known about the early life history of species like haddock.

A COMPARISON OF LARVAE OF THE FRESHWATER AND ESTUARINE SCULPIN, Myoxocephalus quadricornis L. FROM NORTH AMERICA. I. MORPHOLOGICAL DEVELOPMENT

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Morphologically similar sculpins known as Myoxocephalus quadricornis L. live in freshwater lakes and in coastal arctic waters in northern North America. This morphological study, which is part of a larger, comprehensive study of larval Cottidae, was carried out in order to identify differences and similarities among larvae collected from different habitats. Free-swimming larvae of deepwater sculpins from the Laurentian Great Lakes and of fourhorn sculpins from the Beaufort Sea were collected with conical plankton nets. The morphological development of larvae collected from these bodies of water is described and illustrated. It is shown that larval deepwater sculpins from lakes differ in several distinctive ways from larval fourhorn sculpins living in low salinity arctic waters. These results suggest that freshwater Myoxocephalus larvae from North America are morphologically similar to the same freshwater larvae in Europe while, at the same time, the low salinity Myoxocephalus larvae from North America are similar to those living in low salinity waters in Europe.

ABUNDANCE AND ECOLOGY OF SPRING AND AUTUMN SPAWNING HERRING IN THE GULF OF RIGA

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Investigations on the ecology and abundance of larvae of spring and autumn spawning herring in the Gulf of Riga - the main spawning area of the eastern Baltic herring - carried out during 1956-72, led to the following results:

1. Spring herring

Preliminary assessments of the year-class strength are given on the basis of: (a) index of the abundance of larvae at the age of 45-60 days; (b) abundance of the small-sized food zooplankton in June-July (number of specimens/m^3); (c) statistical parameters (mean length, variability index, standard deviation) of the length of larvae at the age of 45-60 days and (d) mean condition factor for larvae.

The estimates agree well with the abundance of the corresponding 1+ and 2+ groups in catches. There is good correlation between the growth of herring larvae (during the first 60-90 days of life) and the weight of corresponding two year olds. This relation can be used for forecasting.

2. Autumn herring

An inverse relation was obtained between the abundance of larvae in spring and the severity of the previous winter. No correlation appeared between the number of larvae in autumn and the abundance of corresponding year classes in catches. Apparently, the winter temperature was the main factor determining the year-class abundance. This conforms well with data of other authors.

In spring a good relation between the length increment of larvae and the water temperature was observed ($r = 0.918$).

From the lack of correlation between the abundance of food organisms and the growth of larvae one can conclude that in spring the herring larvae are sufficiently supplied with food. The food supply in spring does not appear to be the factor determining the growth and mortality of larvae.

FOOD AND FEEDING OF LARVAL REDFISH IN THE GULF OF MAINE

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Stomach analyses of larval redfish from the Gulf of Maine showed these larvae to be size-selective feeders, ingesting mainly larval and adult copepods. There appeared to be no evidence of preferred copepod species, however, spinous organisms such as crab zoeal in the preferred size range were not present in the stomachs although they were abundant in the water.

Only 11 percent of the 402 larvae had empty stomachs. The dominant prey species did vary between July and September and between areas of high and low larval abundance. However, the quantity did not vary significantly. The larvae did not feed heavily in deeper waters.

Some larvae appeared to be feeding at depths other than where they were captured, suggesting some degree of vertical migration.

MORPHOLOGICAL AND ECOLOGICAL STUDIES OF CLUPEOID LARVAE FROM SOUTHERN BRAZIL

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Larval development of two clupeid fishes, Pellona harroweri and Chirocentrodon bleekerianus, belonging to the subfamily Pristigasterinae is described and figured. The samples were collected in southern Brazil by beam trawl. Morphometrical and osteological studies are made and a systematic status of C. bleekerianus is presented. Chirocentrodon cladileokae Tommasi 1964 is considered a synonym for C. bleekerianus.

The larvae of the two species live only in coastal waters and have similar food requirements.

A discussion about the phylogenetic position of Chirocentrodon is made.

LARVAL MORTALITY IN MARINE FISHES AND THE "CRITICAL PERIOD" CONCEPT

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The "critical period" concept, put forth by Johan Hjort in 1914, holds that poor year classes of certain marine fishes will be characterized by exceptionally high mortality at the end of the yolk-sac stage due to starvation. This concept is reviewed in the light of pertinent information on larval survival, at sea, and in the laboratory.

Larval survival curves based on plankton collections, although difficult to interpret, suggest that there may be pronounced differences between species, and between cohorts within species, at the time of major larval mortality. Early larvae of certain species have been collected at sea apparently in, or near, a state of starvation, and in some cases such larvae have been associated with sparse plankton. Laboratory studies have shown that some types of larvae must encounter relatively high concentrations of food soon after their yolk is exhausted if they are to survive, whereas other types of larvae seem more resistant to food deprivation. Thus the situation is highly variable, but it is likely that in nature at least some larvae, under some conditions, pass through a "critical period" in Hjort's sense of the term. Before the relationship between food availability and early larval survival at sea can be understood, the actual availability of food must be investigated in detail in terms of the small-scale patchiness of food and of larvae.

THE FOOD OF THE LARVAL ANCHOVETA

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The intestines of 12 960 larvae of the Peruvian anchoveta Engraulis ringens J. were examined. The material was taken from 83 plankton samples collected between 1961 and 1969 along the Peruvian coast.

The larval stage is defined from the absorption of the yolk sac to the length of 30 mm, at which size it is possible to observe the development of the stomach in this species. It was found that only 22 percent of the intestines examined contained food organisms, consisting principally of copepod eggs, nauplii and invertebrate eggs. Larvae larger than 11 mm length contained copepodite stages and adult copepods. Copepod eggs and nauplii were most abundant during winter (August and September) and the copepodites during the spring.

Since the food was always found only in the posterior part of the gut, the anterior one seems to be used only as a passage, digestion probably taking place in the posterior part.

Although of only little importance by number, the diatoms Centricae were found specially in the smaller larvae.

The larvae collected during the night had less food in the gut or they were empty; light appears to be an important factor in the process of feeding of anchoveta larvae.

BEHAVIOUR AND STRUCTURE OF THE LARVAL SENSE ORGANS IN A DEEP-SEA FISH (Cataetyx memorabilis)

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Larvae of the deep-sea fish Cataetyx memorabilis Meyer-Rochow 1970, which were born on board to the holotype specimen after being hauled up from a depth of almost 1 400 m, could be kept alive for ten days. Apparently they were born prematurely and thus were able to survive a difference in pressure of approximately 140 atm, a variation in temperature of 16°C as well as profound changes in the composition of the water.

In contrast to the adult (a) the larvae have a prominent lateral line system, which consists of papillae 50 µm wide and roughly 15 µm high comprising up to 8 sensory hairs; (b) the larval eyes are relatively four times larger than those of the adult and they are circular and their position is lateral (adult: oval and dorsal). The larval eye has grouped photoreceptors and other adaptations to vision in twilight, as in the adult the "regio otica" appears to be well developed.

The larval sense organs and the behaviour of the animals on the day they presumably ought to have been born (under natural conditions) are consistent with the observation that larval Cataetyx inhabit the upper zones of the ocean rather than the lightless depths in which the adults live.

DISTRIBUTION PATTERNS OF HAWAIIAN FISH LARVAE: EFFECTS OF CURRENTS AND WATER QUALITY

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Larvae of 299 species representing 64 families of Hawaiian fishes were taken during a survey of 18 nearshore locations adjacent to 6 types of shoreline developments and 13 control locations off Maui, Kauai and Oahu. In contrast to reported even distribution of larvae offshore, the abundance of larvae ranged from 1 to 512 larvae/1 000 m^3 at these shallow (L 20m) stations. Larval density, diversity and number of species were inversely related to developments, however the effect was obscured by turbidity. The species composition of larvae nearshore differed markedly from that of inshore adults. Many larvae of mesopelagic and offshore epipelagic families were found. Conversely, larvae of Scaridae, Acanthuridae, Labridae and Chaetodontidae, families which dominate the inshore fauna as adults, together comprised less than 0.2 percent of the 14 736 larvae taken. The abundance of mesopelagic larvae (e.g., Myctophidae) was found to be inversely related to that of inshore larvae from demersal eggs (e.g., Blenniidae). Zooplankton volume was not simply correlated with fish larval abundance, and was higher inshore.

Data from waters around Molokini, a small islet off Maui, demonstrate the response of larvae to island contact. A 26-fold average increase in larval density was found at the upstream edge of the islet. Smaller (4 x) increases were found downstream.

The high densities of larvae found nearshore suggest that deterioration of water quality would have considerably greater effects than would be predicted from offshore densities or surveys of nearshore adults.

THE ROLE OF LARVAL STAGES IN SYSTEMATIC INVESTIGATIONS OF MARINE TELEOSTS: THE MYCTOPHIDAE, A CASE STUDY

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The lanternfish family Myctophidae is the most speciose and widespread family of mid-water fishes in the world ocean. As presently recognized it contains about 30 genera and 300 nominal species. Their larvae are highly prominent in the plankton and make up about 50 percent of all larvae taken in open-ocean plankton tows.

Our studies of myctophid larvae, on a worldwide basis, have demonstrated that characters of the larval stages of lanternfishes are of great utility in systematic analysis. The genera can be recognized on the basis of eye and body shape, the shape and length of the gut, and by pigment pattern. Within each genus the species can be differentiated by subtle differences in morphology and pigmentation.

Characters of the larvae have provided insight into generic affinities of the lanternfishes, allowing us to construct an evolutionary model of tribes and subfamilies that agrees, in part, with models proposed on the basis of adult characters. The concept of using larval characters in combination with adult characters to delineate phylogenetic lines in Myctophids and in other teleost families is discussed in some detail.

INVESTIGATIONS ON THE DISTRIBUTION OF FISH LARVAE AND PLANKTON NEAR AND ABOVE THE GREAT METEOR SEAMOUNT [1]

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1. The influence of the Great Meteor Seamount on the distribution of ichthyoplankton and ichthyoneuston

The Great Meteor Seamount considerably influences the distribution of plankton. It forms a barrier to the organisms of the deep scattering layer for horizontal extension and the plankton biomass above the seamount was found to be only 1/3 as great as that found beside it.

A reduction in number of fish larval species and also in diversity was obvious in the plankton samples which were taken from above the seamount. The oceanic fish larval types were also less abundant above the seamount. The average number of larvae of two neritic forms, Trachurus sp. and Capros aper, however, was higher above the seamount compared to the samples from the adjacent area. These two species probably inhabit the seamount plateau and due to weak and frequently changing currents their eggs and larvae may develop here without drifting away to deep oceanic zones.

An analysis of the length distribution of fish larvae showed that above the mount mesopelagic oceanic forms in the plankton hauls were represented only by smaller specimens. The length distribution of the larvae of the neritic Trachurus sp. and the epipelagic oceanic Macrorhamphosus sp., however, was the same in both areas. It is likely that the young of mesopelagic forms get more diminished above the seamount as soon as they begin to perform vertical day-night migrations which exceed the depth of the seamount plateau.

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Young of Scomberesox saurus which are entirely euneustic, were not influenced by the seamount either in terms of frequency or in length distribution. Neuston species which stay at the surface only during the night hours were less frequent above the seamount than in the oceanic area. This probably results from vertical migration which exceeds the depth of the plateau, so that the species cannot follow their normal pattern of behaviour.

Probably neither adapted oceanic nor neritic species have been able to "conquer" the relatively small seamount area in a way as to form reproducing stocks over many generations. Thus the seamount must not be considered as a particular biotope. It mainly disturbs the surrounding oceanic biotope, in which it forms a hostile zone. Neritic forms may find a refuge there when they have drifted away from some coastal zones.

2. Fish larval composition of 12 horizontal hauls from a depth of 25 m

Every four hours 12 horizontal ring trawl hauls were done at a depth of 25 m at a permanent station near the Meteor Seamount. These samples were different from oblique tows in the frequency of several fish larval types. Like the neuston hauls the horizontal ring trawl hauls also showed how fish larvae were caught more successfully when only the zone of their main distribution is fished.

Three subsequent hauls of the total of 12 were strikingly different in their fish larval composition. In these samples the numbers of mesopelagic species were much higher and epipelagic species were lower. Because day-night periodicity did not seem to be the reason for this phenomenon and because the hydrographical situation in the area investigated was very stable, it is assumed that internal waves had influenced the vertical distribution of the fish larvae.

THE LARVAL TAXONOMY OF PRIMITIVE MYCTOPHIFORM FISHES

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The larval stages of some primitive myctophiform fishes were reviewed with special references to the most generalized myctophoid family Aulopidae. A series of life history stages of the Japanese aulopid, Hime japonica (Tanaka), was studied in detail and compared with those of the Atlantic ally, Aulopus filamentosus Cloquet. The larval specimens of other families such as Synodontidae, Chlorophthalmidae, Ipnopidae (so-called Macristiella specimen), Bathysauridae (so-called Macristium specimen), Neoscopelidae and Bathypteroidae were also included in this study. In the larval taxonomy of these fishes, the following characters appeared to be most relevant: (1) number of peritoneal pigment spots, (2) shape, size and location of fins, (3) position of anus, (4) number of branchiostegals and (5) vertebral (myotome) counts.

The close relationship between Aulopidae and Synodontidae was confirmed and, at the same time, the association between Aulopidae, especially the Japanese aulopid and Chlorophthalmidae was also indicated clearly. Possibly two lines diverged from the aulopid-like ancestral stock, one lineage contained Aulopidae, Synodontidae and perhaps Bathysauridae, and the other one contained the remaining four families.

BRAIN DIMENSION AND GROWTH STAGE

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The growth of the brain has been followed in young herring (Clupea harengus) and trout (Salmo trutta) reared in the laboratory. For a 50-fold increase in body weight occurring during larval and metamorphic life, the brains of herring increase in weight by 40-fold and their cell numbers (as measured by total DNA) by some 15-fold. This pattern is independent of age (in days) and rearing conditions but closely reflects growth stage. The relationship of these findings to brain measurements made on wild populations, and to the comparison of one population with another, will be discussed. They tend to confirm the brain as the organ that represents the animal.

SEASONAL VARIATION OF ICHTHYOPLANKTON IN THE ARABIAN SEA WITH RESPECT TO THE MONSOON

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The distribution and seasonal variation of the total fish eggs and larvae of commercially important groups such as Clupeoids, Synodontidae, Anguilliformes, Bregmacerotidae, Exocoetidae, Carangidae, Serranidae, Coryphaenidae, Scianenidae, Stromateidae, Labridae, Callionymidae, Trichiuridae, Gempylidae, Scombridae, Scomberomoridae, Thunnidae, Gobiidae, Scorpaenidae and Pleuronectiformes, based on the 694 vertical hauls (200 - 0 m) made during the International Indian Ocean Expedition, are discussed.

Most collections (88 percent) were from offshore and oceanic waters. Fish eggs are represented in 70 percent of the collections with a seasonal coverage of twelve months, their peak periods of occurrence being June-July and October. December, January and February are the poor seasons for fish eggs. Fish larvae were represented in 92 percent of the samples, the groups under discussion in total being represented in 17 percent of the collections. They are collected in almost all months of the year, the peak period being July and November. The minimum number was collected in April and September.

The southwest and northeast monsoons seem to play an important role in the distribution of fish eggs and larvae. The general pattern of eggs and larvae distribution is more or less similar, but there are a few common places such as the northeastern half of the Arabian coast, northern tip of Somali coast, Kerala coast, southwest coast of Sri Lanka and some areas along the equator, where the abundance of eggs and larvae is very high. During the southwest monsoon period the fish eggs and larvae are found to be two to three times more abundant than in the northeast monsoon season, especially in areas such as the Somali coast, the Arabian coast, the west coast of India including Wadge Bank area. This might be due to the greater intensity of the southwest monsoon, its longer duration and the consequent changes in the environment. The Arabian Sea surface water has high salinity, high temperature and a steep gradient of dissolved oxygen falling to very low values at 100-150 m depth. The subsurface water has an even higher salinity, but low temperature and less dissolved oxygen content. Further correlation on the abundance of the various families of fish larvae is also made with respect to temperature, salinity and primary and secondary production.

The oceanic region has large resources of Thunnidae, Scomberomoridae, Trichiuridae, Gempylidae, Coryphaenidae, Labridae and Exocoetidae. In the offshore waters in addition to Bregmacerotidae, Serranidae, Carangidae, Labridae, Gobiidae, Callionymidae and Stromateidae, there are large resources of engraulids.

SOME FACTORS INFLUENCING EARLY SURVIVAL AND ABUNDANCE OF *Clupeonella* IN THE SEA OF AZOV

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Some regularities in the abundance fluctuations of the Azov "tiulka" (*Clupeonella delicatula*) have been established as a result of a study of the effect of various environmental factors on year-class strength. The factors considered included salinity, sea condition, light intensity, oxygen and temperature regimes, and feeding conditions of larval fish. A method of determining the significance of one factor when other factors are at an optimum level was used, which made it possible to establish the dominant importance of the temperature regime during embryonic development. It has been found that poor year classes are formed in years when temperatures optimal for the development of eggs (15-18°C) continue for ten days, while there is a sharp increase in year-class strength when these favourable temperatures continue for an average of 20 days.

RESISTANCE OF PLAICE EGGS TO MECHANICAL STRESS AND LIGHT

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Effects of light and mechanical stress, associated with wave action, were investigated as potential factors contributing to mortality during early development of the eggs of plaice (*Pleuronectes platessa*).

The average force necessary to burst the egg capsule increased from 1.5 gf to 600 gf at the end of gastrulation, followed by a slow decrease until hatching. Except during the first few hours after fertilization, pressures at lethal deformation were higher than those which are produced by the usual form of breaking waves on the open sea. Mechanical stress applied through bubbles, or through water either sprayed or suddenly decelerated, produced little or no egg mortality. Experiments with natural and artificial light showed that lethal effects on plaice eggs were mainly due to the ultraviolet component. However, tolerance limits of the eggs to total solar radiation were higher than usual insolation levels in the southern North Sea during the spawning season. The results indicate that wave action and light are unlikely causative factors in those instances in which high mortality of plaice eggs has been reported in the literature.

LARVAL ABUNDANCE IN RELATION TO STOCK SIZE, SPAWNING POTENTIAL AND RECRUITMENT IN NORTH SEA HERRING

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Series of larval abundance estimates of the Downs and Doggerbank herring were compared with parallel series of stock size and recruitment parameters. Similar comparisons were made in the past for the Downs herring (Cushing and Bridger, 1966), for the central North

Sea (Zijlstra, 1970) and for the northwestern North Sea (Saville, 1971). The paper reappraises former conclusions, taking into account possible effects of temperature during spawning. For both areas the major part of the variance in annual estimates of larval abundance appeared to be generated by variations in egg production and temperature conditions during spawning. Attempts to associate stock size or larval abundance with subsequent recruitment yielded inconclusive results.

SURVIVAL OF AUSTRALIAN ANCHOVY EGGS AND LARVAE IN A HEAT TRAP

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The Australian anchovy (Engraulis australis) off Victoria and southern New South Wales is an estuarine (inlets, bays and salt lakes) spawner. Spawning occurs in summer (September to February) and eggs and larvae are exposed to ambient temperatures of 20 to 25°C. Water from Munmorah Lake passes through a power station cooling system where its temperature rises 7-8°C; it is then released into Lake Bugewoi. Since the two lakes are joined, a continuous circulation or thermal trap is formed, with a lake volume displacement time of three days. Growth, survival and temperature tolerance of anchovy eggs and larvae from the outer feeder lake (open to the sea) were compared to those in the Munmorah-Bugewoi system. Most eggs and larvae can survive the thermal trap, but are currently near their upper thermal limit. Excessively hot summers or a raising of power output in the plant, could result in the death of most anchovy eggs.

GYNOGENESIS IN 'HYBRIDS' WITHIN THE PLEURONECTIDAE

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The well known plaice/flounder hybrid produced by fertilizing plaice (Pleuronectes platessa) eggs with sperm from the flounder (Platichthys flesus) is highly viable and, at least for males, fertile. The reciprocal cross, however, is not successful. The embryos in flounder eggs fertilized by plaice sperm are grossly abnormal and rarely survive to hatching. They closely resemble the haploid embryos which can be obtained following radiation-induced gynogenesis. Similarly abnormal embryos were also obtained from plaice eggs fertilized by halibut (Hippoglossus hippoglossus) sperm. In both cases of apparent hybrid haploidy, the maternal species has smaller eggs than the paternal species and measurement of sperm head suggests that there is also a corresponding variation in the size of the spermatozoa.

The hypothesis that the flounder/plaice and plaice/halibut hybrids are gynogenetic haploids is discussed in relation to attempts to induce diploidy by cold-shock treatments which are known to be effective in radiation-induced gynogenesis.

REARING OF GILT-HEAD *Sparus aurata*

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The levels of external factors (temperature, photoperiod and feeding) inducing maturation in *Sparus aurata* were ascertained and more than 40 immature fish were captured and kept through to sexual maturity. Hydration of the eggs followed spawning in females by injection of gonadotropin at a rate of 800 i.u/kg live weight. The eggs released were fertilized by naturally spawning males in the spawning tank.

The eggs, hitherto unknown, show very precise characters during development, which lasts 48 hours at 18° C. At hatching the larvae, which are 2.5 mm long, are mainly still and float near the surface, ventral side up. The mouth is not open and the eyes are unpigmented. A day later the larvae spread into the body of the water and adopt a vertical, almost immobile position. After two days the eyes become pigmented, the mouth is openable and the larva become predatory.

Experiments were conducted to define the type and quantity of prey species required in the rearing medium:

3-7 days after hatching:	*Fabrea salina* or young *Brachionus plicatilis*; 5-10/ml
8-25 days after hatching:	*Brachionus plicatilis*; 1/ml
25-70 days after hatching:	*Artemia salina* nauplii copepodites and young adult *Eurytemora velox*; 2-5/ml

After about 70 days the larvae show morphological and ecological characters similar to the adult and can be fed on dry particles.

The following aspects of the experiments are described: daily rates of feeding at each stage, changes in behaviour and predation success. In addition, an attempt is made to explain three periods of high mortality and the larval morphogenesis, hitherto unknown, is described.

NITROGEN WASTE PRODUCT METABOLISM IN THE EGGS AND FRY OF RAINBOW TROUT

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Knowledge concerning nitrogen waste product metabolism in teleost embryos and larvae is severely lacking, and only an energetic study by Smith (1946) quantitated nitrogen excretion from trout eggs. In this study, it was hypothesized that impermeable trout eggs may retain metabolic products until after hatching. Therefore, if toxic ammonia accumulated within the egg, it may stimulate conversion to urea via the ornithine-urea cycle pathway, thus ascribing an embryonic function to a pathway recently found in several adult teleost livers, but described as non-functional.

The present study was largely concerned with the metabolism of nitrogen waste products, i.e., type of waste products produced, synthetic pathways, and rates of accumulation and/or excretion. The following parameters were measured at several stages of egg and fry development: ammonia, urea, uric acid, arginine, nitrogen excretion, and ornithine-urea cycle enzyme activities.

Ammonia, urea and arginine accumulated within the egg during development, with both urea and arginine declining in concentration soon after hatching. The hypothesis of urea retention in the egg as an ammonia detoxifying mechanism was not supported because (1) the eggs were quite capable of nitrogen excretion; (2) the ornithine-urea cycle was incomplete, and (3) toxicity studies revealed high levels of ammonia tolerance by eggs and sac fry, suggesting little need to detoxify ammonia.

ANALYSIS OF THE TAXONOMIC CHARACTERS OF YOUNG SCOMBRID FISHES, GENUS Thunnus

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The specific identification of larval scombrids has been based primarily on the distribution of melanophores on various parts of the body. Examination of these pigment distributions has revealed a great amount of variability as to exact location and number of melanophores on larvae in the genera of Thunnus from the Atlantic Ocean. Specimens from which melanophore data were obtained were cleared and stained for study of the osteology and for accurate identification. Results have shown that melanophore distributions are unreliable characters for specific identification. This is particularly evident where western Atlantic larvae identified as T. albacares, T. alalunga or T. obesus using the traditional melanophore character method, were found to be T. atlanticus based on osteological features.

DISTRIBUTION AND MORTALITY OF SOLE (Solea solea (L)) EGGS IN INSHORE AREAS

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Surveys of the distribution of sole eggs and larvae in 1969-70 off the English east coast were carried out using a "Lowestoft 30 cm diameter high-speed Plankton Net". This provided samples over the whole coastal spawning area (1970) and the whole spawning season in a restricted area (1969).

Individual samples of sole eggs were sorted into developmental stages and the production of the stages at each station compared within years. No significant differences were found in the proportion of stages in different locations in 1970.

The production of the developmental stages in samples were then considered to be dependent only on the numbers present in the area and the duration of each stage.

Laboratory experiments over the biotic range of temperature for sole eggs enabled the duration of each stage to be allowed for in the calculation and plot of production of sole eggs in a coastal population. The slope indicated a mortality of about 60 percent per day and a total egg mortality of more than 95 percent for both the 1969 and 1970 studies.

EFFECTS OF CADMIUM ON DEVELOPMENT AND SURVIVAL OF HERRING EGGS

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Herring eggs from Baltic spring and autumn spawners were exposed to different concentrations of cadmium (0.1; 1.0; 5.0; 10.0 ppm) immediately after fertilization and incubated under constant conditions (temperature: 10.2 ±0.51 °C; salinity: 15.94± 0.21 per mille S; pH: 8.14± 0.14). Observations were made on survival of eggs until hatching, incubation time, viable hatch, percentages of malformations, total length of hatched larvae, yolk size, diameter of eye and size of the otic capsule. In additional series of experiments, the influence of different cadmium concentrations was studied in the presence of EDTA, zinc and ascorbic acid. Incubation time (50 percent hatching time) was reduced considerably with increasing cadmium concentration. Percentages of viable hatch were 16.3 percent, 82.7 percent and 93.0 percent in 1.0, 0.1 ppm Cd and the controls, respectively. In a concentration of 5.0 ppm Cd no viable hatch occurred. In 10.0 ppm Cd less than 10 percent of the embryos survived until hatching, but most did not develop otic capsules. The effect of cadmium was diminished in the presence of zinc and EDTA, resulting in larger larvae and higher survival. Cadmium concentration in experimental water and in the eggs of different developmental stages were determined using Perkin-Elmer flameless atomic absorption equipment (Type 300, with graphite furnace HGR 1). The herring eggs were dissolved in 150 µl of an HNO_3 - H_2SO_4 - mixture (4:1 V/V) and diluted with bidistilled water to an appropriate concentration for the AAS measurements.

Uptake of cadmium by herring eggs is rather rapid, reaching a stable level some hours after the beginning of exposure. The maximum levels attained depend on the initial cadmium concentration of the test media. Immediately before hatching, the amount of cadmium determined in herring eggs dropped considerably, and hatched larvae contain virtually no cadmium. Eggs incubated in cadmium-EDTA mixtures generally take up virtually no cadmium until the chelating capacity of EDTA is fully utilized.

Cadmium uptake takes place mainly at the surface of the egg capsule, causing a change in physico-chemical properties of the chorion. The ionic form of cadmium in the water is important for the action of toxicity mechanism.

RELATIONS BETWEEN EGG PRODUCTION, LARVAL PRODUCTION AND SPAWNING STOCK SIZE IN CLYDE HERRING

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From 1958 to date the Marine Laboratory, Aberdeen, has conducted surveys of herring egg and early larval production over Ballantrae Bank, the spawning ground of the spring spawning Clyde herring stock. For a variety of reasons, valid estimates of egg production were obtained only in seven years of this series, and of larval production in only eleven years of the series. These have been compared with estimates of absolute spawning potential of the stock in these years calculated from the catch, mortality rate and fecundity-weight relationship of the mature stock.

There is a significant relationship between the estimates of egg deposition and spawning potential of the stock in the same year. The relation between spawning potential and larval production is fitted by a curve with an asymptote at a value of about 6×10^{12} on the spawning potential axis. The possible reasons for this are discussed, as is its significance in stock management, and interpretation of larval production as a measure of stock size.

ON THE RELIABILITY OF METHODS FOR QUANTITATIVE SAMPLING OF FISH LARVAE

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A short review is given of results from studies on the efficiency of Bongo high-speed plankton samplers and different models of modified Gulf III in catching fish larvae. Additional results on extrusion and filtration efficiency from comparative fishing are included. The partly contradictory results are discussed under the aspects of gear handling and the distribution of fish larvae. The dependence of the accuracy of sampling on handling of gear and availability of ancillary equipment are shown, and the feasible precision of quantitative estimates, based on sampling with modified Gulf III, are discussed.

VERTICAL MIGRATION OF ATLANTO-SCANDIAN HERRING LARVAE

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The material was collected at thirty diurnal ichthyoplankton stations. The herring spawning grounds appear to be occupied by cold, low salinity coastal waters, but spawning occurs in warm Atlantic waters at a depth down to 220 metres.

As aquaria observations show, Atlanto-Scandian herring larvae stay on the bottom for the first two days after hatching and then become pelagic. Before active feeding commences, larvae show a positive reaction to light which stimulates their ascent to the upper sea layers. It seems that larvae are better able to make the transition to external food sources in the illuminated upper layers as sight is the main receptor used during feeding.

Although small larvae keep to the bottom layers, diurnal vertical migrations start at the end of the yolk-sac stage when the larvae are about 9 mm long. A temperature difference of the order of 1.0-1.5 ^{o}C is no barrier to vertical migration.

EFFECTS OF REDUCED OXYGEN ON EMBRYOS AND LARVAE OF SOME FRESHWATER FISHES

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Embryos and resulting larvae of four fish species were subjected to reduced oxygen concentrations at optimal temperatures and a flow of 60 ml/min (velocity about 3.3 cm/min) until all fish were feeding. White suckers (Catostomus commersoni (Lacépède)) and walleyes (Stizostedion vitreum vitreum (Mitchell)), were not harmed at 50 percent saturation of dissolved oxygen. White sucker development was delayed at 25 percent saturation and walleye survival dropped at 35 percent. Developmental delay and mortality of coho salmon (Oncorhynchus kisutch (Walbaum)) increased progressively with each reduced oxygen concentration tested, including the highest reduced tension, 50 percent saturation. Good survival and slight delays in the development of brook trout (Salvelinus fontinalis (Mitchell)) occurred at all reduced concentrations down to 20 percent saturation, where poor survival occurred. All species died at 12.5 percent saturation.

DEVELOPMENT OF THE RESPIRATORY SYSTEM IN HERRING AND PLAICE LARVAE

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At hatching the gill structures are almost completely lacking except for gill arches which are present in the larvae. Respiration must therefore be cutaneous and possibly through the gut. The relative importance of the fin and body areas is considered, the fin area clearly being of more importance in the younger larvae. Despite the very different pattern of development in herring and plaice, the total surface area increases as the square of the length. The secondary lamellae appear at 22 mm length in herring and 9 mm length in plaice larvae. Gill area then increases rapidly in both species with length, but the slope of the relationship tends to decrease at and after metamorphosis. In the juvenile stages the gill area/weight relationship is similar to adult fish of the same species, though in herring the gill area per unit weight is 3.5 times that of plaice.

Tests using benzidine showed the presence of precursors of haemoglobin in the early feeding stages long before the blood turns pink at metamorphosis. Quantitative measurements of haemoglobin using the pyridine method showed a rapid increase in its synthesis around metamorphosis, possibly linked with the decrease in the gill area/body weight ratio at and after metamorphosis.

EFFECT OF HYDROGEN SULPHIDE ON DEVELOPMENT AND SURVIVAL OF EIGHT FRESHWATER FISH SPECIES

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Toxicity of hydrogen sulphide to fish is from undissociated H_2S and is strongly influenced by temperature, O_2 and pH. Eggs and larvae of Lepomis macrochirus, Pimephales promelas, Stizostedion v. vitreum, Salmo gairdneri and Carassius auratus were subjected to acute toxicity tests (96-hour LC_{50} and threshold). At 22°C the 96-hour LC_{50} of eggs varied from 0.014 to 0.022 mg/litre. Lowered O_2 (3 mg/l) retarded egg development and decreased survival in H_2S treatments. Sac fry had LC_{50}'s from 0.007 to 0.025 mg/l in different species. Variation in percentage survival from 100 to 0 percent occurred with changes in H_2S levels as low as 0.005 mg/litre. Lethal deformity of fry hatched from eggs incubated in non-lethal treatments of H_2S was as high as 54.2 percent. Length at hatching was reduced up to 18 percent. Reduction of temperature from 25°C to 6°C increased tolerance of fry to H_2S from 15 to 25 fold but lengthened the incubation period. Levels of naturally occurring H_2S in potential egg deposition areas of ponds and streams varied from 0.08 to 0.10 mg/l, greatly in excess of LC_{50} for both eggs and fry. Importance of H_2S in both natural and polluted systems has been overlooked because inadequate sampling technique near the bottom water interface has failed to show presence of low levels continuously evolved and demonstrated to be lethal. It is concluded that H_2S may limit reproduction in many habitats.

SEASONAL CHANGES IN THE DIMENSIONS AND VIABILITY OF PILCHARD EGGS

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A grid of 30 stations was sampled monthly from August 1969 to November 1970, using a modified 1 m net hauled obliquely at 4 knots. The large numbers of pilchard eggs in the samples were graded into the series of stages described by Gamulin and Hure (1955), and the viability assessed subjectively.

There was considerable seasonal variation in egg diameter and in diameter of the yolk mass and oil globule, apparently related to environmental temperatures, the smaller eggs occurring in summer and the larger in winter. There is a possibility that two different groups of fish could be present. The smaller summer eggs are closer in size to those found in the Mediterranean Sea and other southern localities.

Overall mortality averaged 50 percent, varying from 38 percent in August to 92 percent in February, and some correlation between sea temperature and egg viability is indicated. Most of the dead eggs belonged to stages II, III and IV. The pronounced improvement in viability at stage V must be related to closure of the blastopore, as appears to be the case in the Venezuelan anchovy, and comparisons can be made with Rollefsen's observations on liability to mechanical damage in the early stages of cod eggs. However, it seems possible that ionic regulation may be involved.

ARTIFICIAL GYNOGENESIS AND ITS APPLICATION IN GENETICS AND SELECTIVE BREEDING OF FISHES

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Gynogenesis was investigated as a method to provide unisex populations for introductions of exotic fish into the U.S.A. Literature on gynogenetic fishes, cytology, and methods for producing gynogenetic animals suggest an approach to unisex production.

Gynogenetic goldfish (Carassius auratus) were produced in low numbers using x-irradiated white amur (Ctenopharyngodon idella) sperm on goldfish eggs. Cold-shock of fertilized goldfish eggs did not increase yield. Three gynogenetic goldfish survived from 10 000 eggs. Of 10 000 goldfish eggs fertilized with white bass (Roccus chrysops) sperm, five developed; one survived. A total of 151 haploid and 34 diploid embryos hatched out of 40 000 white amur eggs which were fertilized with x-irradiated goldfish sperm and cold-shocked. No eggs hatched in controls, heat-treated eggs, or after colchicine treatment.

Gynogenetic offspring theoretically can reproduce if the female of the species has heterogametic sex chromosomes, if spontaneous sex inversions occur, or by natural gynogenesis. Production of gynogenetic fishes allows stocking exotic species without likelihood of reproduction.

Gynogenesis is valuable in locating and selecting recessive genes, in studies of chromosome linkage, and gene crossovers. In selective breeding, it is more valuable than inbreeding since homozygosity may be achieved in fewer generations.

SIGNIFICANCE OF EGG AND LARVAL SURVEYS IN THE STUDY OF POPULATION DYNAMICS OF FISHES

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Japanese sardine (Sardinops melanosticta) used to be the most important neritic-pelagic fish in the Japanese fisheries, but the catch declined drastically after 1941. The nation-wide cooperative investigation was started in 1949; however, analysis of the catch and effort data faced serious difficulties because the sardine is landed by a number of small boats using different types of gear. Tagging experiments are not feasible for the sardine. Estimation of the abundance of sardine eggs was attempted and the results were promising. The total abundance of eggs spawned in the area west of Kyushu in 1952, for instance, was estimated at 100×10^{12} and the sampling error was about 17 percent. Assuming an equal sex ratio and two levels of fecundity, 60 000 and 100 000, the number of spawning adults would be 3.3×10^{9} or 2.0×10^{9} and the rate of exploitation would be a quarter or two fifths. The operating cost of the spawning survey, excluding personnel expenses, was roughly estimated at Yen 2 500 per sample. The above estimate for the sardine is based on 453 samples and the total cost would be a little more than Yen 1 million. This amount is considered to be quite reasonable in relation to the information obtained.

LABORATORY STUDIES OF PREDATION BY EUPHAUSIIDS ON FISH LARVAE

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The abundant euphausiid in the California Current, Euphausia pacifica, may be an important predator of fish larvae. Laboratory experiments showed that when the number of yolk-sac anchovy larvae (Engraulis mordax) was not limiting the median number eaten per day by larval E. pacifica was two; juvenile euphausiids eat seven and adults seventeen. The carbon requirements of E. pacifica for the three growth stages is similar to the carbon provided (9 µg/larva) by the median feeding rates. Within the adult euphausiid group, feeding on fish larvae significantly increased with increasing animal size; however, no size-specific feeding could be demonstrated for juvenile euphausiids. All replicate experiments with individual E. pacifica were conducted with the juveniles. These studies showed that the amount of feeding on yolk-sac anchovy larvae was not affected either by the addition of another prey, imposed starvation, moulting or the length of time the euphausiids were in captivity. The amount of feeding increased as the prey density was increased from one to ten larvae offered per day per 3.5 litres; further increases had no effect. Feeding rate was constant regardless of time of day. The percent capture of fish larvae by euphausiids was lower than usual when older, more active anchovy larvae were offered. These studies are discussed in terms of field data collected in the area of the California Current where Euphausia pacifica and anchovy larvae co-occur.

PRESENT STATE OF BILLFISH LARVAL TAXONOMY

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Two families, Xiphiidae and Istiophoridae comprise the billfishes of the world; the former is monotypic, the latter has eleven species in three genera. The species include: Xiphias gladius, cosmopolitan; Istiophorus platypterus, I. albicans, Atlantic and

Indo-Pacific; Tetrapturus angustirostris, Indo-Pacific; T. belone, Mediterranean; T. georgei, Mediterranean and northeastern Atlantic; T. pfluegeri, Atlantic; T. albidus, Atlantic; T. audax, Indo-Pacific; Makaira nigricans, Atlantic; M. mazara, Indo-Pacific; and M. indica, Indo-Pacific Oceans.

Larvae of X. gladius, I. platypterus, T. angustirostris, T. audax, M. nigricans, M. mazara and M. indica have been described. The identification of these species, largely from the Indo-Pacific, have been presented. Larvae of some Atlantic species were tentatively identified on the assumption that they resemble the Indo-Pacific cognate species. The clarification of larval identification for Atlantic species is necessary, particularly in the genus Tetrapturus.

The identification of small billfish larvae has depended chiefly on head morphology such as snout length, head profile, spination and pigmentation pattern on the lower side of the head. The problem remains, however, that some of the diagnostic characters are difficult to interpret and their use would require much experience. It is suggested that variations in the morphological characters of larvae of some billfishes could be due to geographic differences.

THE VERTICAL AND SEASONAL DISTRIBUTION OF FISH EGGS AND LARVAE AT OCEAN WEATHER STATION "INDIA" IN RELATION TO THE BIOLOGICAL AND PHYSICAL OCEANOGRAPHY OF THE AREA

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The vertical distribution of the zooplankton in the upper 500 m at station "India" ($50^{\circ}00'N-19^{\circ}00'W$) was determined from a series of oblique hauls using Longhurst-Hardy Plankton Recorders. The hauls were taken at weekly intervals from the end of March to the beginning of October during 1971 and 1972. Included in this sampling programme was an intensive study of primary production by the C_{14} method, chlorophyll a, species composition of the phytoplankton, nutrients, temperature and salinity.

Fish eggs and larvae were identified and their distributions plotted in no/m^3 over the sampling period. The most abundant fish eggs were the characteristic eggs of Maurolicus muelleri (Gmelin), which first appeared in early April and reached peaks of abundance in both years of 5 eggs/m^3 in late June at depths between 150 m and 200 metres.

During 1971 the eggs were distributed down to 500 m in late July and August. The distribution of Maurolicus eggs closely followed the $9^{\circ}C$ isotherm, the eggs remaining in water between 8.8° and $10^{\circ}C$. Nine species of fish larvae were identified from the LHPR hauls. These were: Argyropelecus hemigymus (Cocco, 1829), Benthosema glaciale (Reinhardt, 1937), Cyclothone braneri (Jespersen and Tåning, 1926), Maurolicus muelleri, Micromesitius poutassou (Risso, 1826), Molva byrekelange (Walbaum, 1788), Myctophum punctatum (Rafinesque, 1810), Onogadus (Gaidropsarus) argentatus (Reinhardt, 1842). The most abundant of these larvae were those of M. muelleri which reached densities of 20 larvae/m^3 in the surface waters (0-30 m) in September 1971. The majority of the larvae were distributed in the upper 200 m in both years.

The annual distribution of abundance of the fish larvae were correlated with the available food, the main predators such as Sagitta maxima (Connant, 1896) and the prevailing physical parameters.

THE ABILITY OF HERRING AND PLAICE LARVAE TO AVOID CONCENTRATIONS OF OIL DISPERSANTS

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The responses of larvae to horizontal and vertical gradients of oil dispersant in sea water have been studied. Horizontal gradients were established in a five-channel fluvarium in which the concentrations of dispersant increased in a stepwise manner across the test yard. In each run, the positions of ten larvae were noted every 30 sec for 30 min and their mean positional values (mpvs) calculated for each 2 min interval. No marked avoidance reactions were noticed even at 30 parts/10^6, the highest concentration tested. However, the mpv tended to clean water values with all concentration gradients. This tendency was also time-dependent. These changes in distribution resulted from increased activity of the larvae in the dispersant and not from a chemo-taxis.

Vertical gradients were established by carefully layering the dispersant onto sea water. Larvae did not avoid any of the concentrations tested (1-100 parts/10^6) but remained in the dispersant layer until they became narcotized. These inactive animals sank into clean water where they recovered and swam upward again into the toxic layer. This pattern endured over 48 hours.

It is concluded that fish larvae are unable to detect the dispersants at these concentrations and would not avoid areas of dispersants at sea. However, because of the effect of dispersants larvae would sink or swim from lethal concentrations.

THE FEEDING OF FISH LARVAE IN THE SOUTHERN BIGHT OF THE NORTH SEA IN RELATION TO THE DISTRIBUTION OF FOOD ORGANISMS

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The distributions of plaice and sand-eel larvae in the Southern Bight are described, and compared with the distribution of Oikopleura, which for a part of the larval life of both species is their most important food. The effect of the fish larvae on the distribution and abundance of the prey organism is calculated from estimates of their feeding rates, and compared with the field data. The effect on the plaice larvae of finding themselves in different concentrations of Oikopleura is assessed using a condition index which has been studied experimentally. Some data for 1963 are discussed, a year during which Oikopleura was very scarce in this region.

Data on the distribution and feeding of dab, flounder and cod larvae are also presented, and some of the problems attending the analysis of other predator/prey systems within the plankton community are specified.

EARLY LIFE HISTORY OF *Limanda yokohamae* (Günther)

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The Japanese Government is interested in developing culture of flatfishes. The potential use of these methods in coastal aquaculture led to the present investigations on artificial rearing of eggs and larvae.

Fertilized eggs were reared at six constant temperature conditions. Hatching occurred at temperatures of 5, 10 and 15°C, but not at 2.5, 20 and 25°C.

Egg survival to hatching was 50 percent at 5°C, 70 percent at 10°C, and 10 percent at 15°C. The relation between temperature (x) and incubation period (days) is expressed by the formula:

$$y = 33.89e^{-0.11817x}$$

At a temperature of 8°C, metamorphosis started about 32 days after hatching and was completed after about 18 days.

As the adult of *Limanda yokohamae* closely resembles that of *Limanda schrenki*, Yamamoto (1951) suggested that *L. yokohamae* is a synonym of *L. schrenki*. However, the present paper shows morphological differences which separate *L. yokohamae* and *L. schrenki* as two different valid species.

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